Master's Thesis

Màster Universitari en Enginyeria Industrial (MUEI)

Control and Simulation of Power Converters for HVDC Grids

Annexes

19th June 2019

Author: Víctor Silos Sánchez

Director: Eduardo Prieto Araujo

Convening: June 2019

Escola Tècnica Superior
d'Enginyeria Industrial de Barcelona

Abstract

In these Annexes, the schemes, the code and the graphs that have been performed in Matlab-Simulink® are presented.

In Annex A, the simulations performed in the **Case 1: Equal proportional gains**, using the multi-terminal HVDC grid defined in Chapter 4 of the Thesis, are presented.

In Annex B, the simulations performed in the **Case 2: Different proportional gains**, using the multi-terminal HVDC grid defined in Chapter 4 of the Thesis, are presented.

In Annex C, the simulation performed in the **Case 3: Disconnection of a WFVSC converter**, using the multi-terminal HVDC grid defined in Chapter 4 of the Thesis, is presented.

In Annex D, the demonstration of the current loop equation and the active power expressions are presented.

In Annex E, the schemes created using the software Matlab-Simulink® to perform the simulations are presented. Furthermore, it is explained the function carried out by the specific blocks used to create these models.

In Annex F, the computer code written in Matlab® is presented. Sometimes, it has had to do line breaks in the code pasted from Matlab® due to the margins of the document.

Contents

List of Figures

Annex A

Simulations of Case 1: Equal proportional gains

The solver chosen for each simulation has been the ode4 (Runge-Kutta) with a fixed-step size of 10^{-5}.

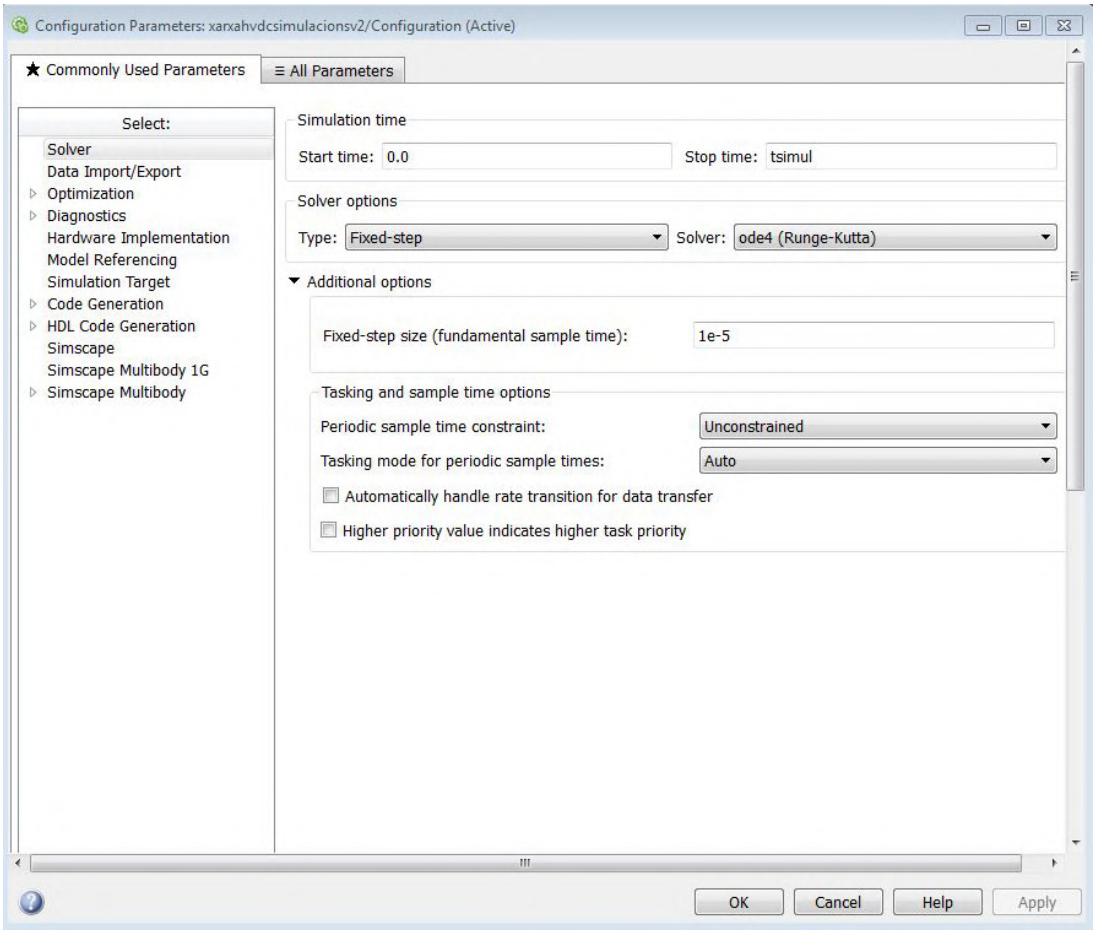

Figure A.1: Configuration parameters of the solver

A.1 Simulation 1

Simulation 1: $K_{pDC} \in [0, 1800]$ with a step of 200. In total 10 simulations for each electrical magnitude.

A.1.1 Voltages and currents of the multi-terminal HVDC grid

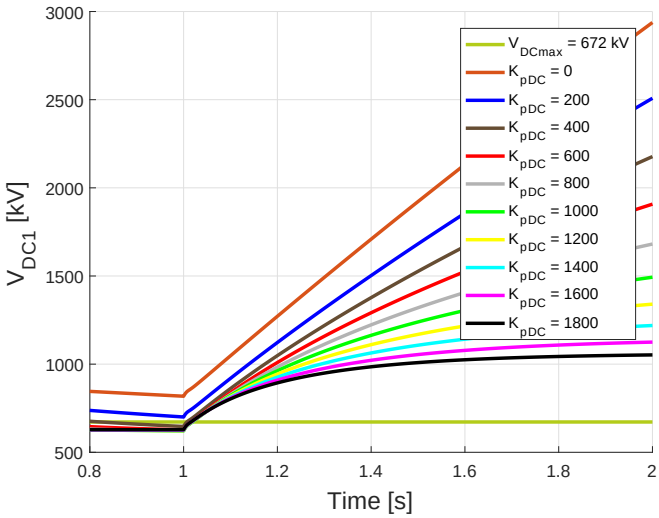

Figure A.2: Voltage V_{DC1} from simulation 1 of Case 1

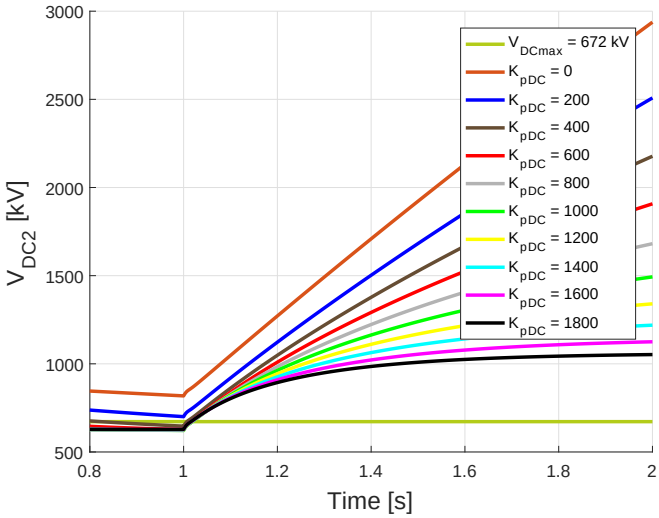

Figure A.3: Voltage V_{DC2} from simulation 1 of Case 1

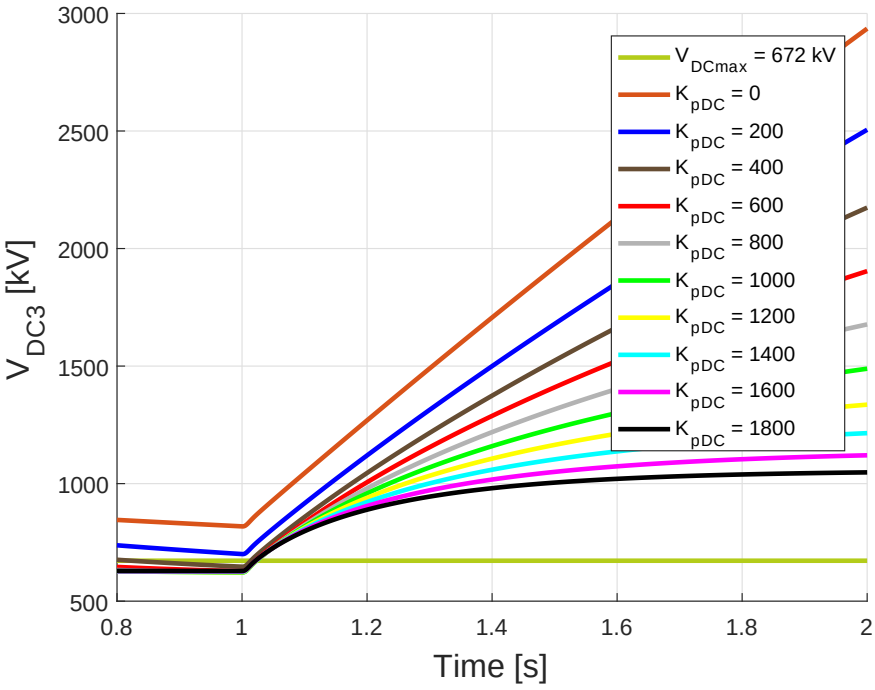

Figure A.4: Voltage V_{DC3} from simulation 1 of Case 1

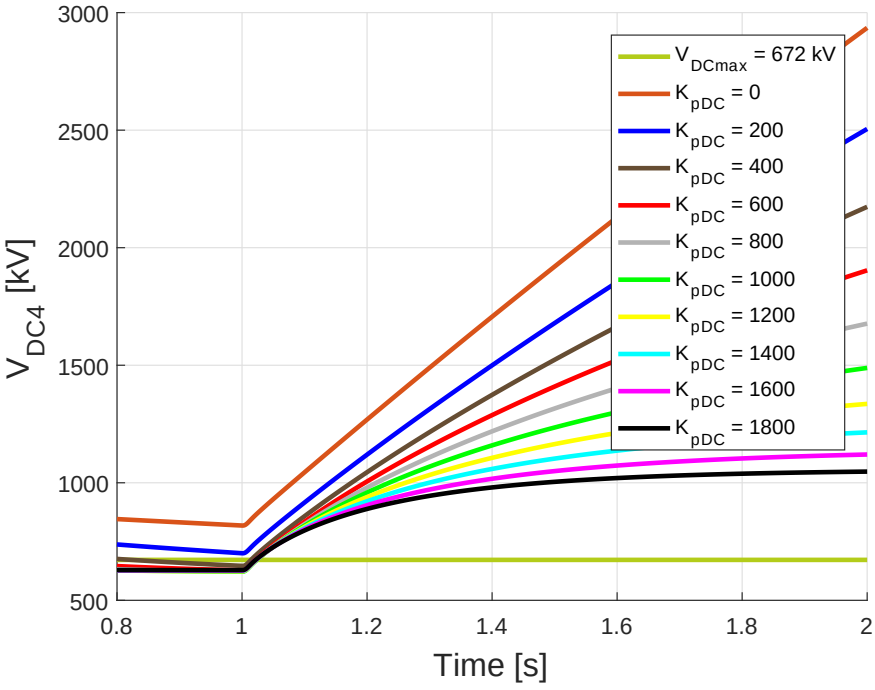

Figure A.5: Voltage V_{DC4} from simulation 1 of Case 1

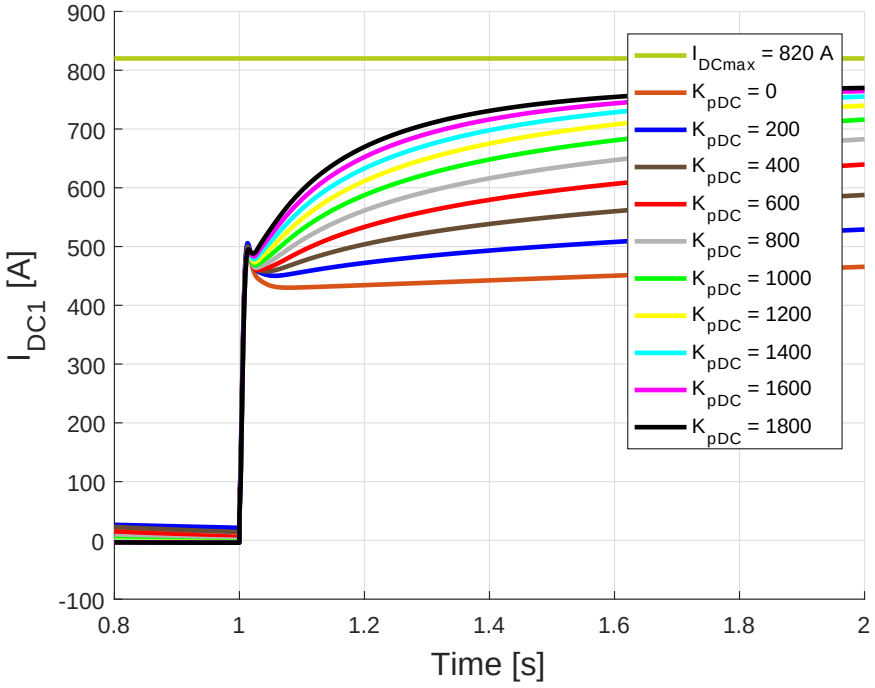

Figure A.6: Current I_{DC1} from simulation 1 of Case 1

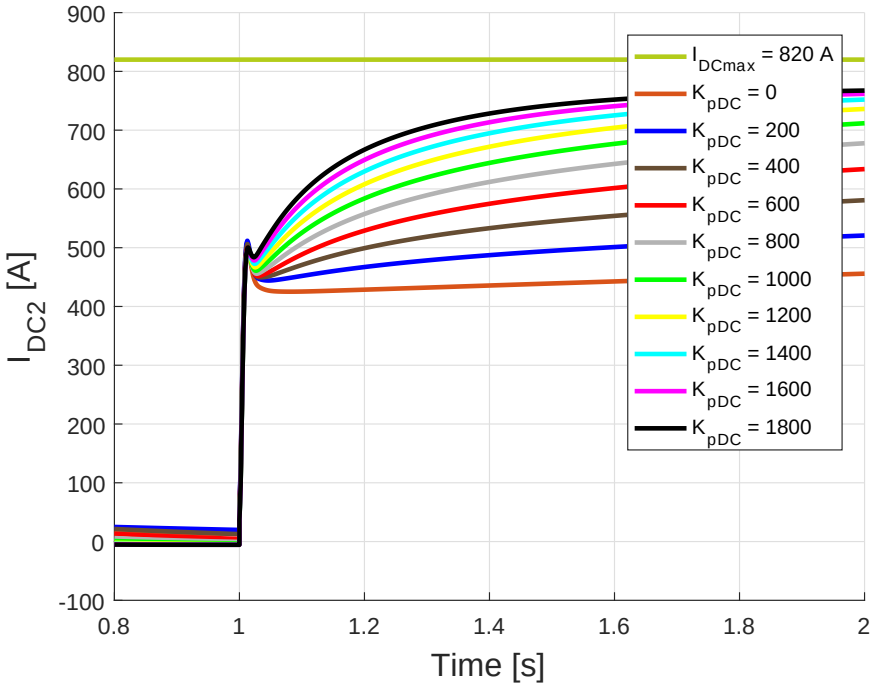

Figure A.7: Current I_{DC2} from simulation 1 of Case 1

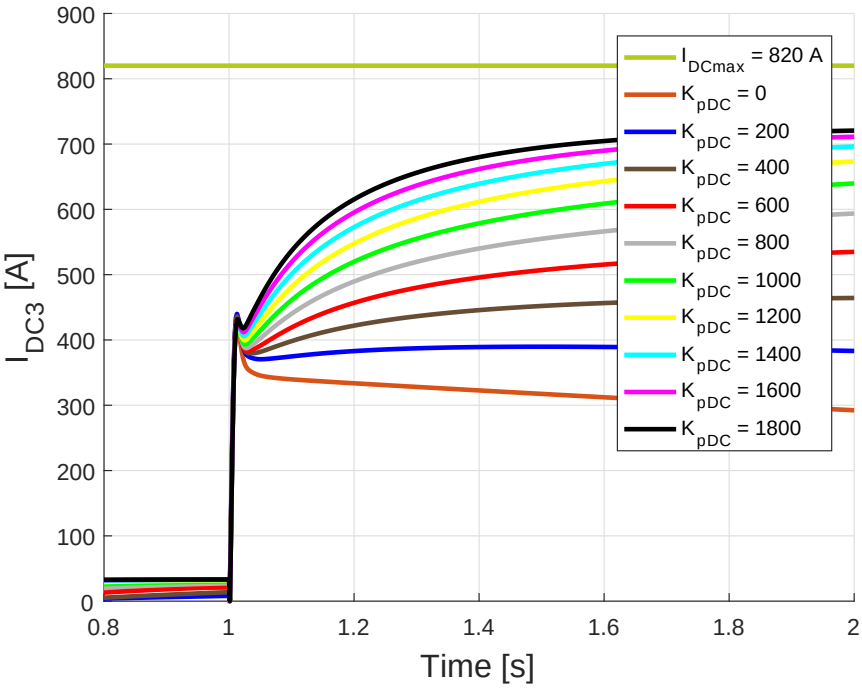

Figure A.8: Current I_{DC3} from simulation 1 of Case 1

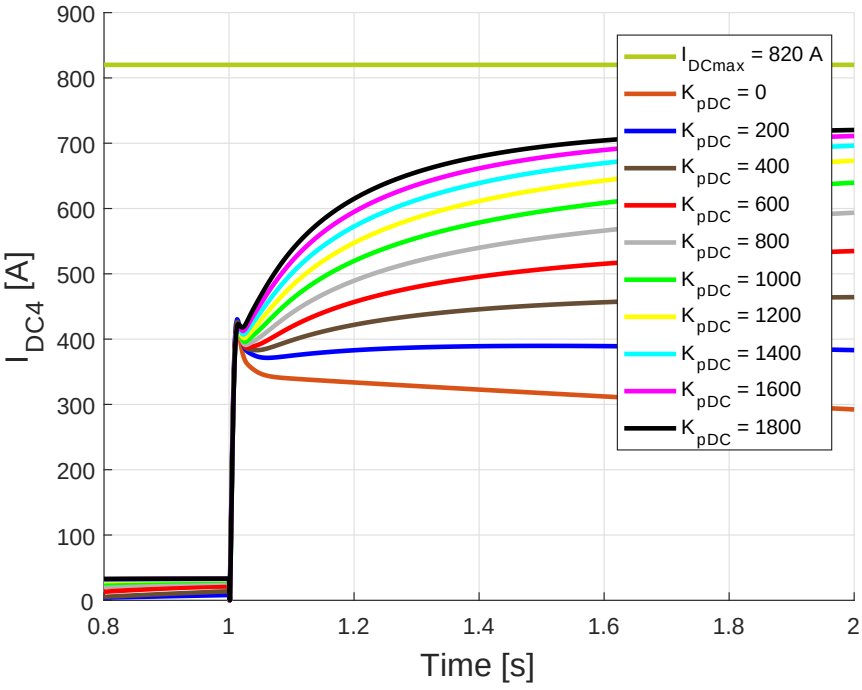

Figure A.9: Current I_{DC4} from simulation 1 of Case 1

A.1.2 Voltages and currents of power converter 1

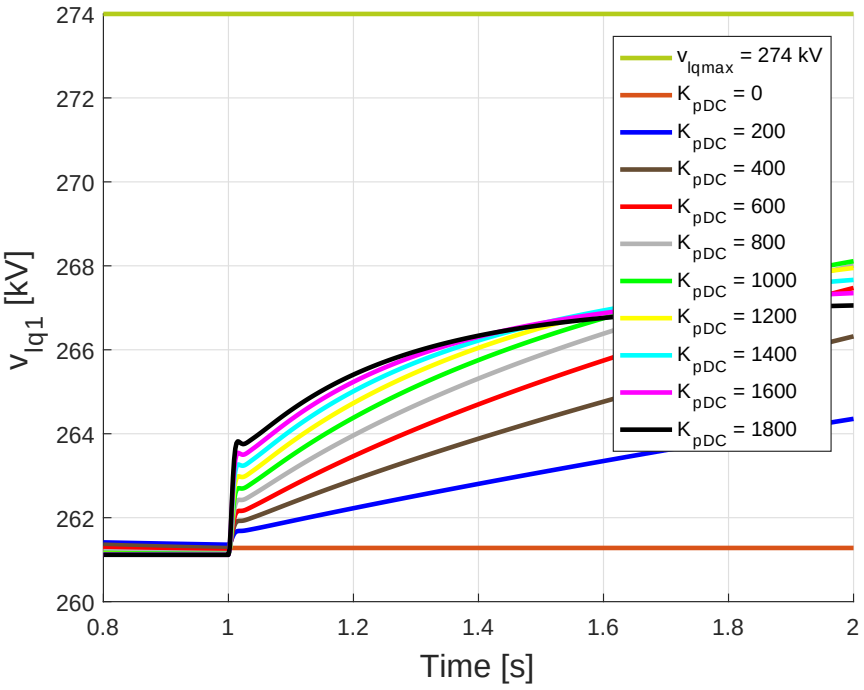

Figure A.10: Voltage v_{lq1} from simulation 1 of Case 1

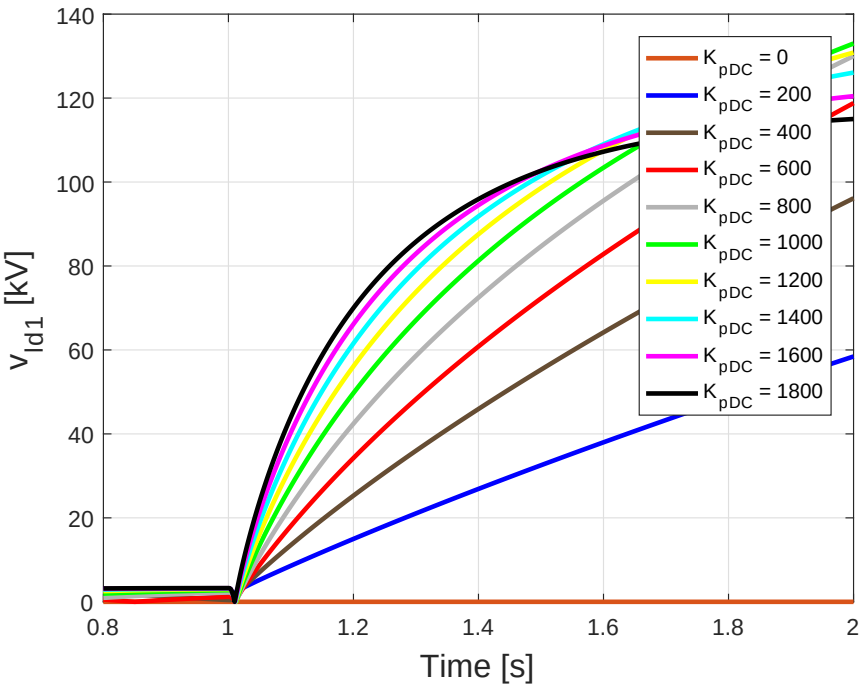

Figure A.11: Voltage v_{ld1} from simulation 1 of Case 1

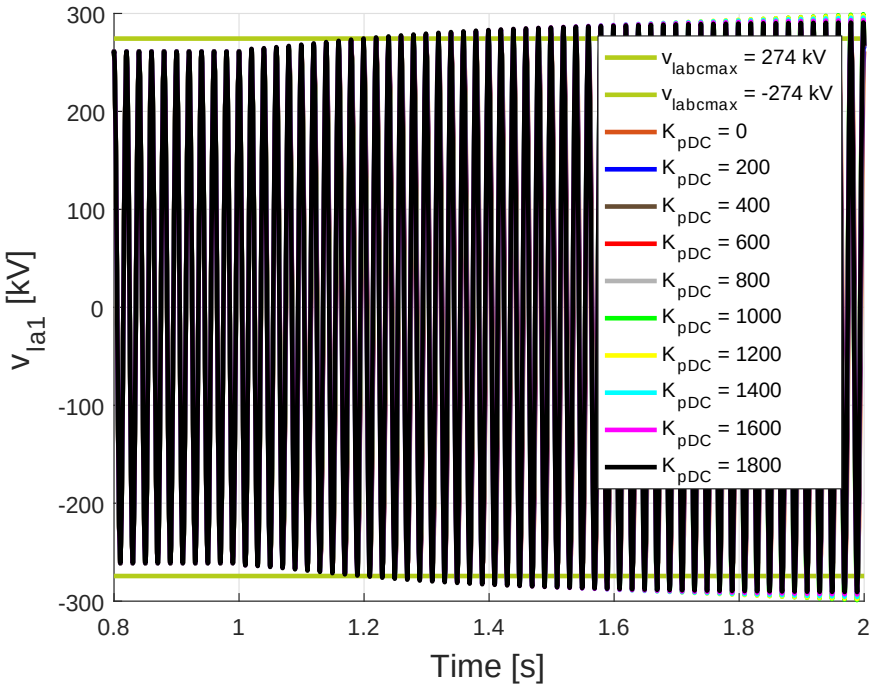

Figure A.12: Voltage v_{la1} from simulation 1 of Case 1

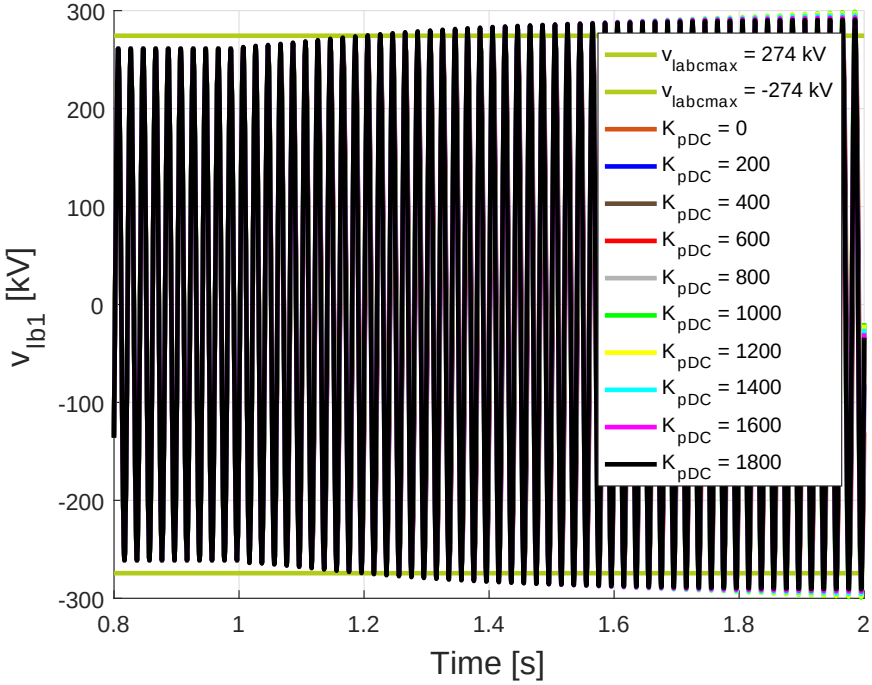

Figure A.13: Voltage v_{lb1} from simulation 1 of Case 1

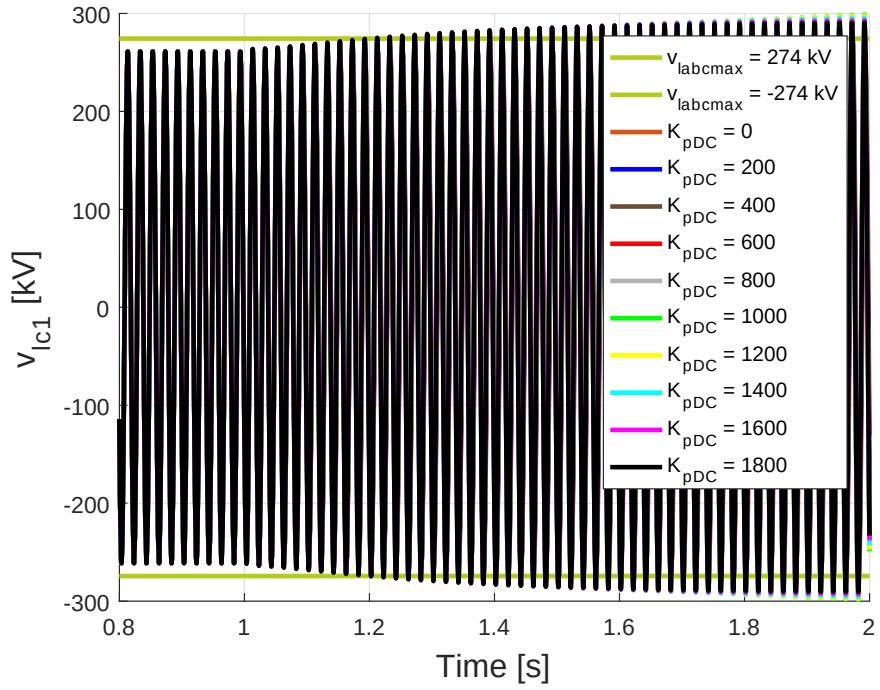

Figure A.14: Voltage v_{lc1} from simulation 1 of Case 1

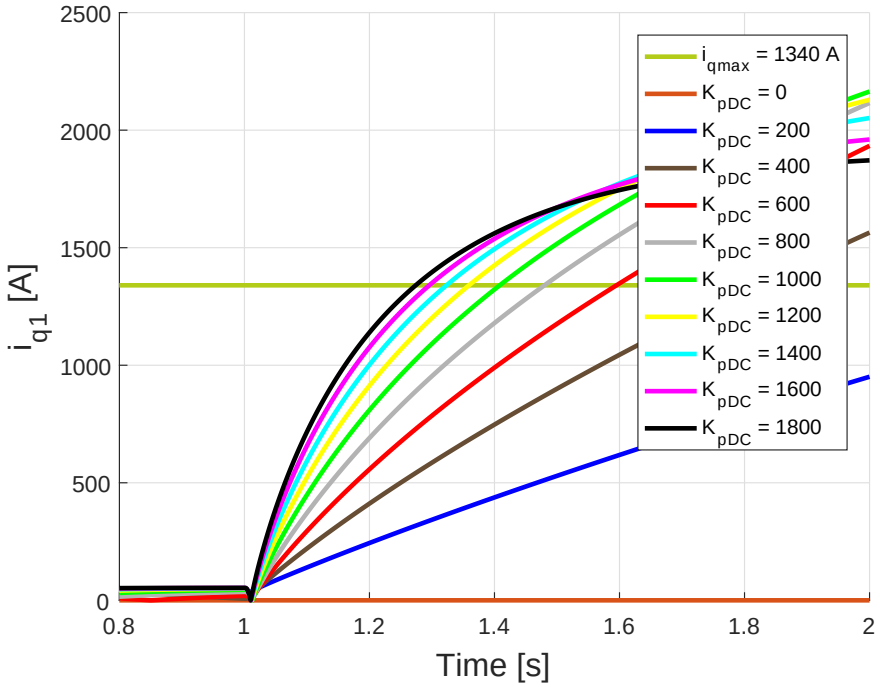

Figure A.15: Current i_{q1} from simulation 1 of Case 1

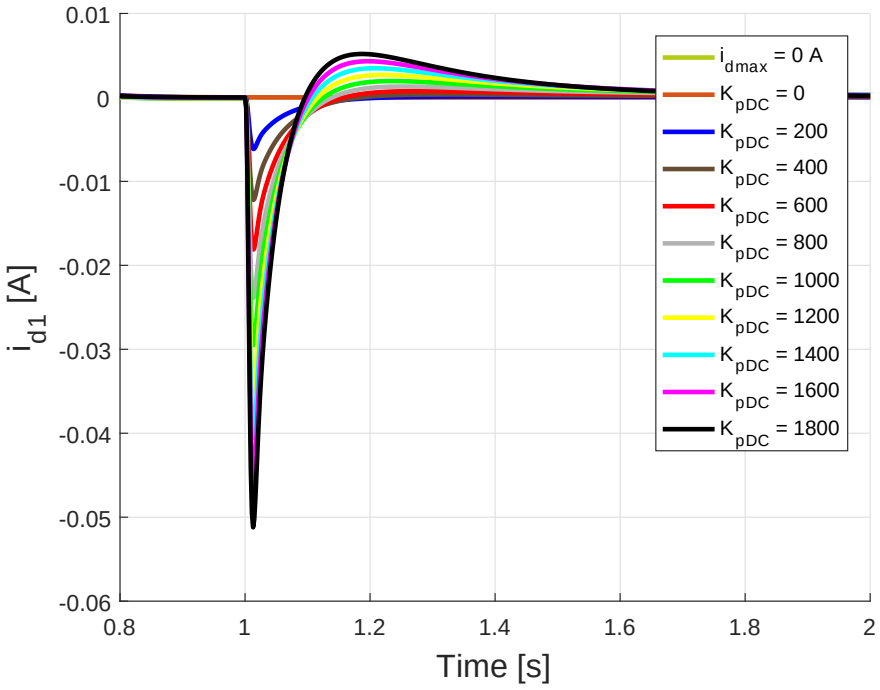

Figure A.16: Current i_{d1} from simulation 1 of Case 1

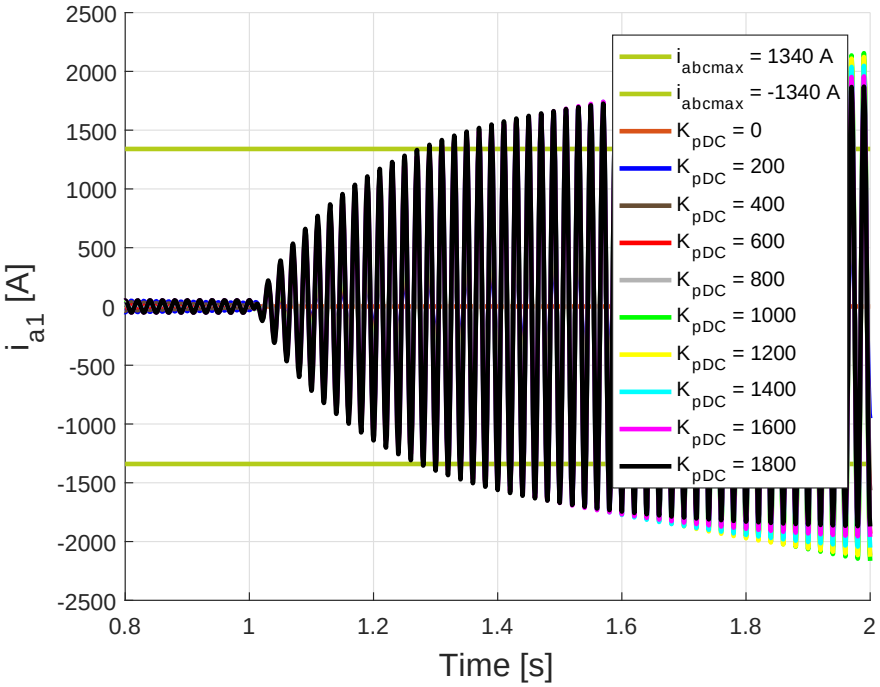

Figure A.17: Current i_{a1} from simulation 1 of Case 1

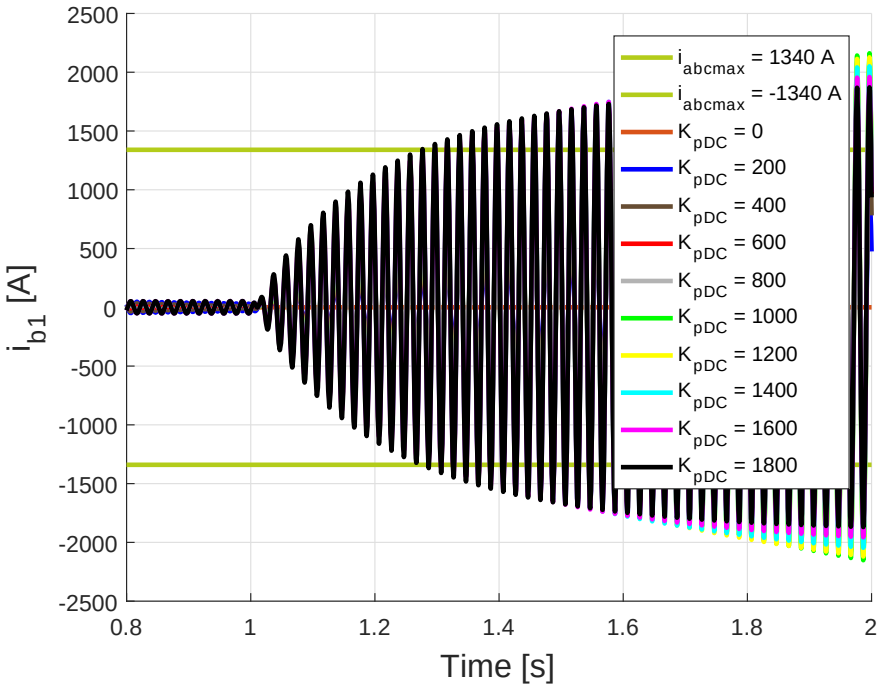

Figure A.18: Current i_{b1} from simulation 1 of Case 1

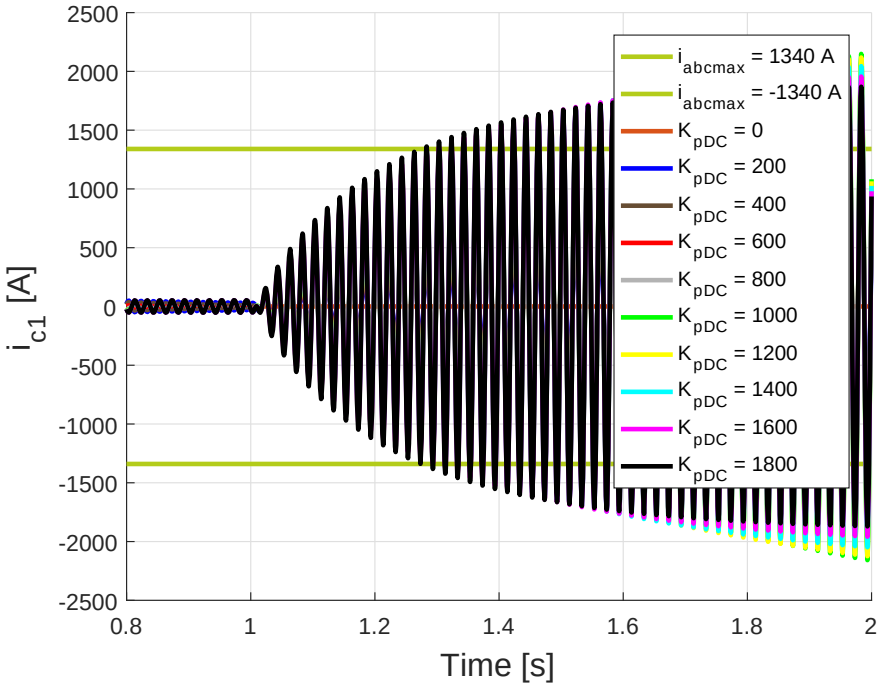

Figure A.19: Current i_{c1} from simulation 1 of Case 1

A.1.3 Voltages and currents of power converter 2

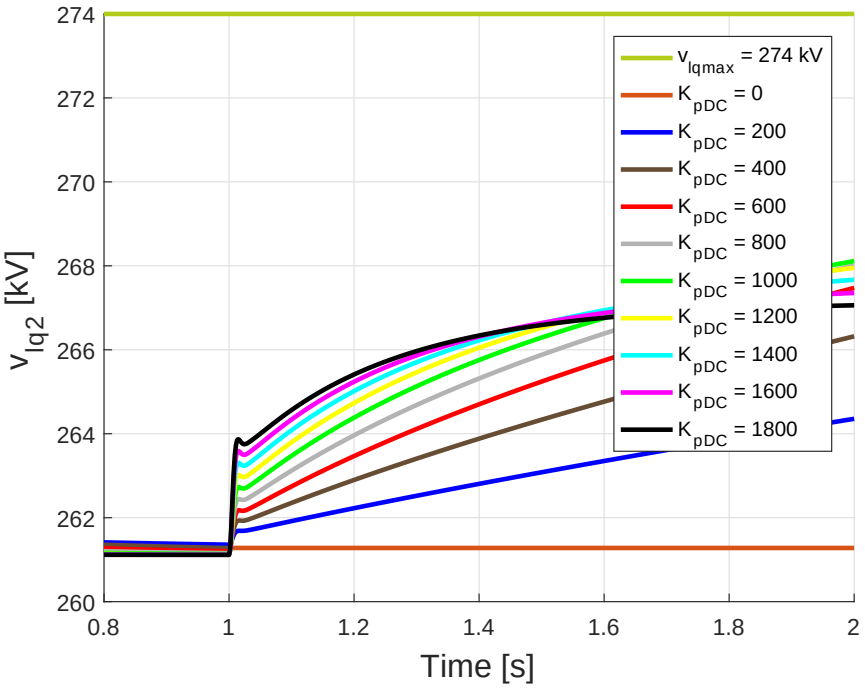

Figure A.20: Voltage v_{lq2} from simulation 1 of Case 1

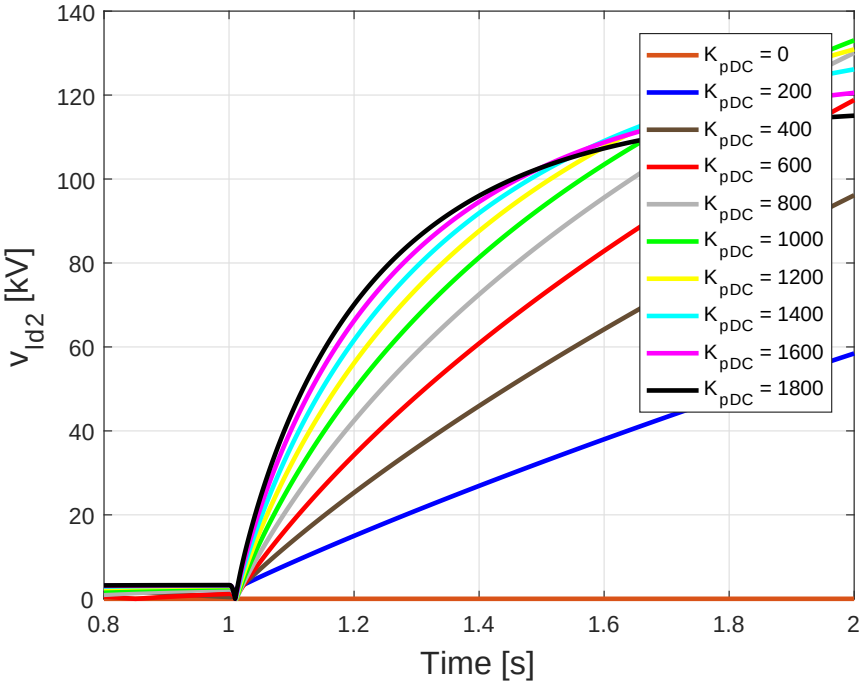

Figure A.21: Voltage v_{ld2} from simulation 1 of Case 1

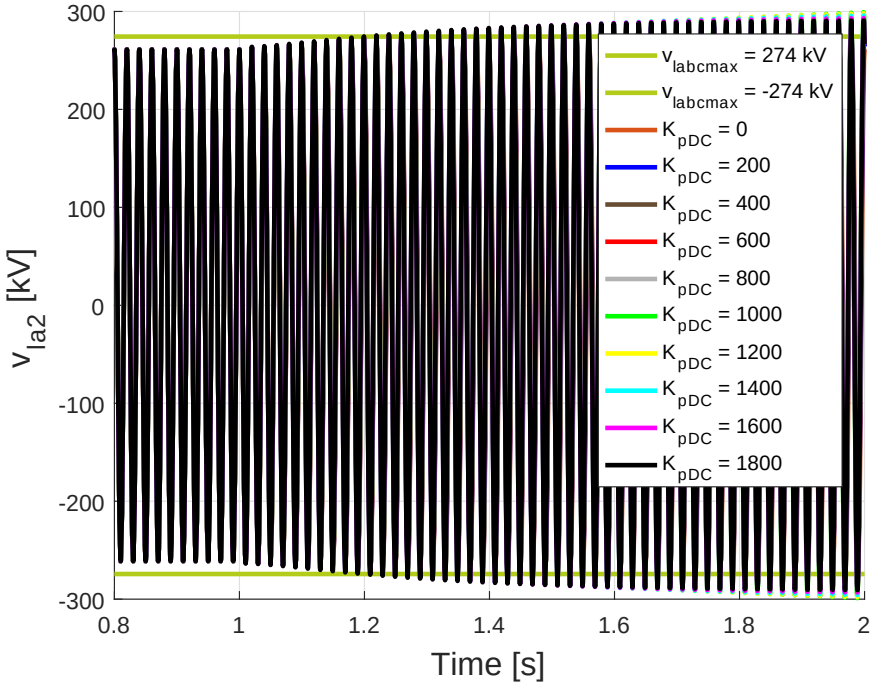

Figure A.22: Voltage v_{la2} from simulation 1 of Case 1

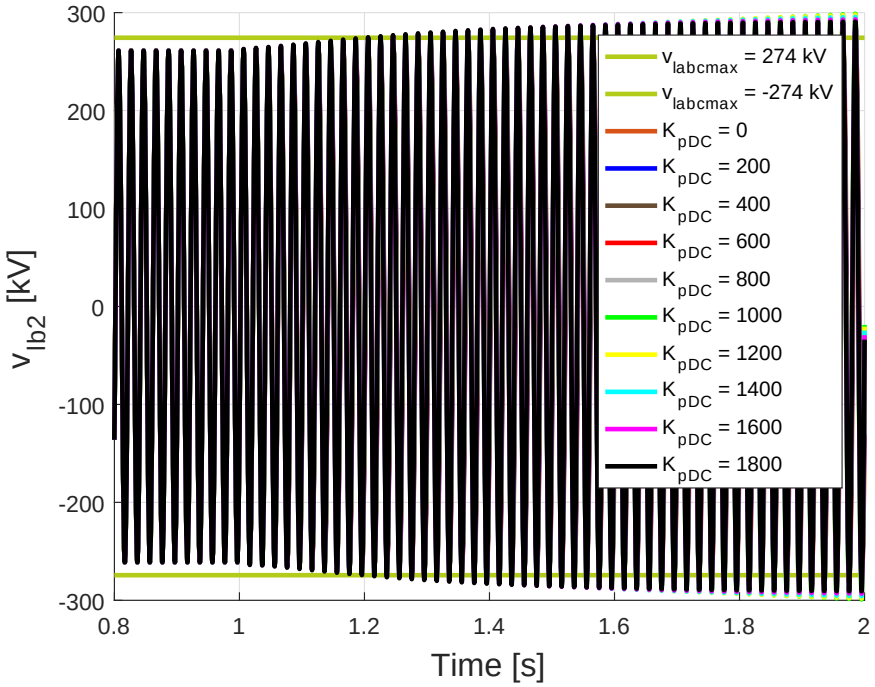

Figure A.23: Voltage v_{lb2} from simulation 1 of Case 1

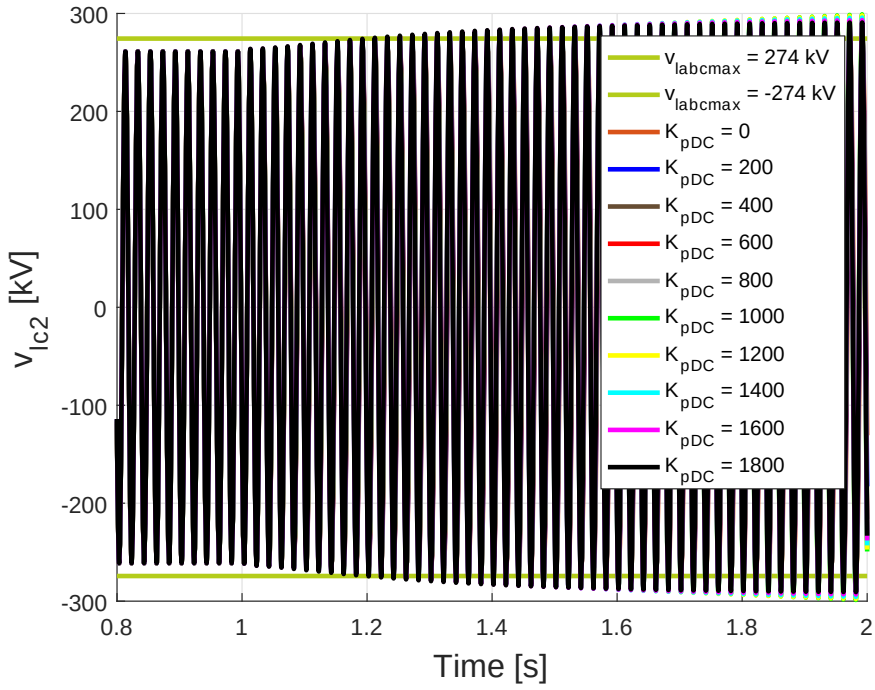

Figure A.24: Voltage v_{lc2} from simulation 1 of Case 1

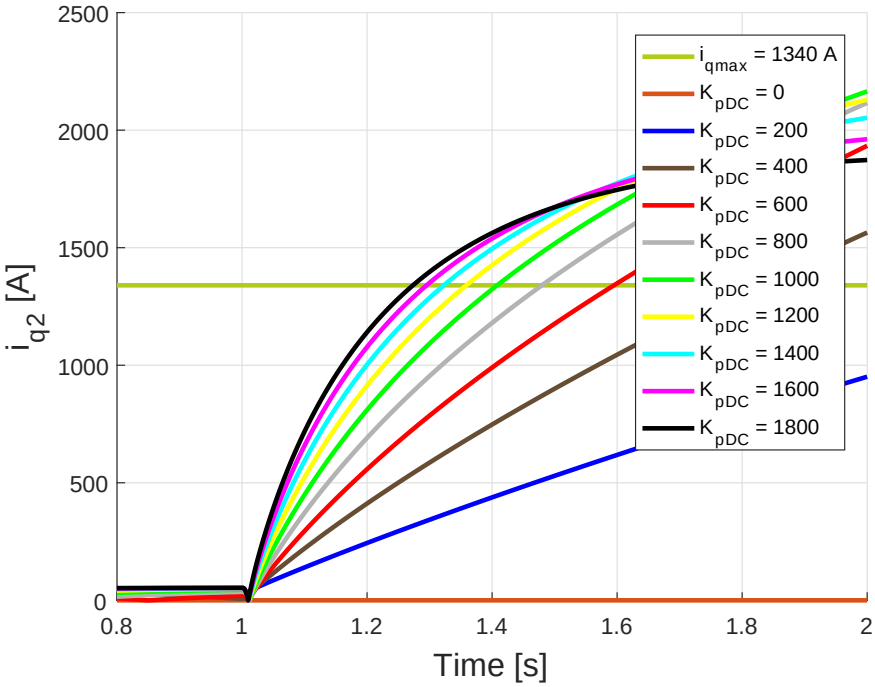

Figure A.25: Current i_{q2} from simulation 1 of Case 1

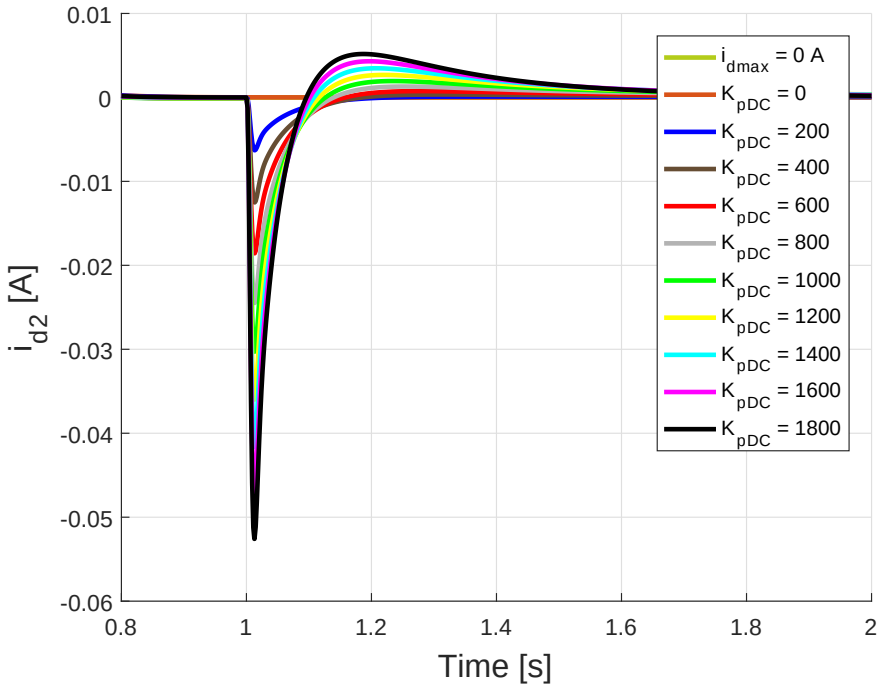

Figure A.26: Current i_{d2} from simulation 1 of Case 1

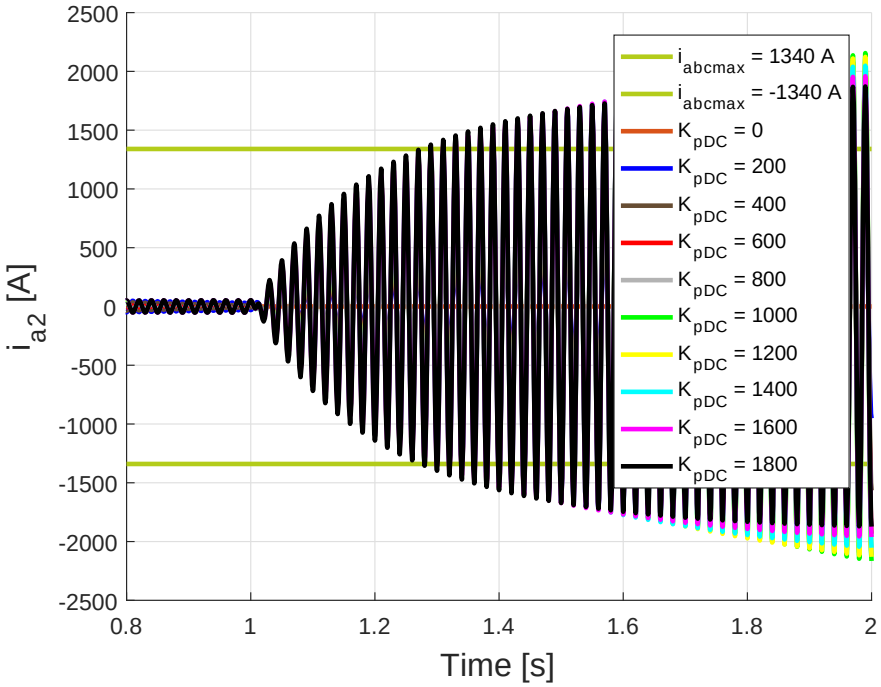

Figure A.27: Current i_{a2} from simulation 1 of Case 1

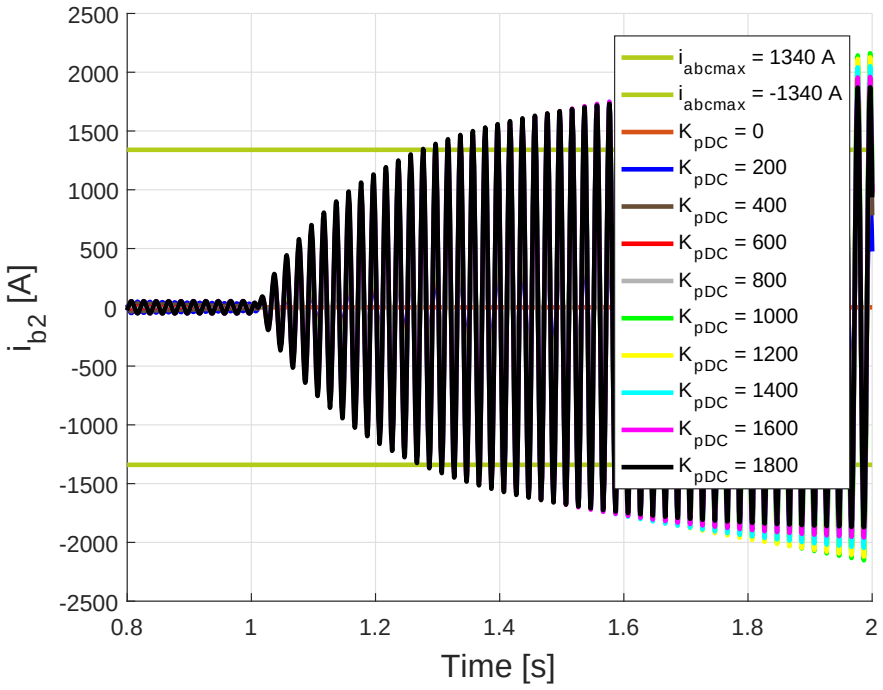

Figure A.28: Current i_{b2} from simulation 1 of Case 1

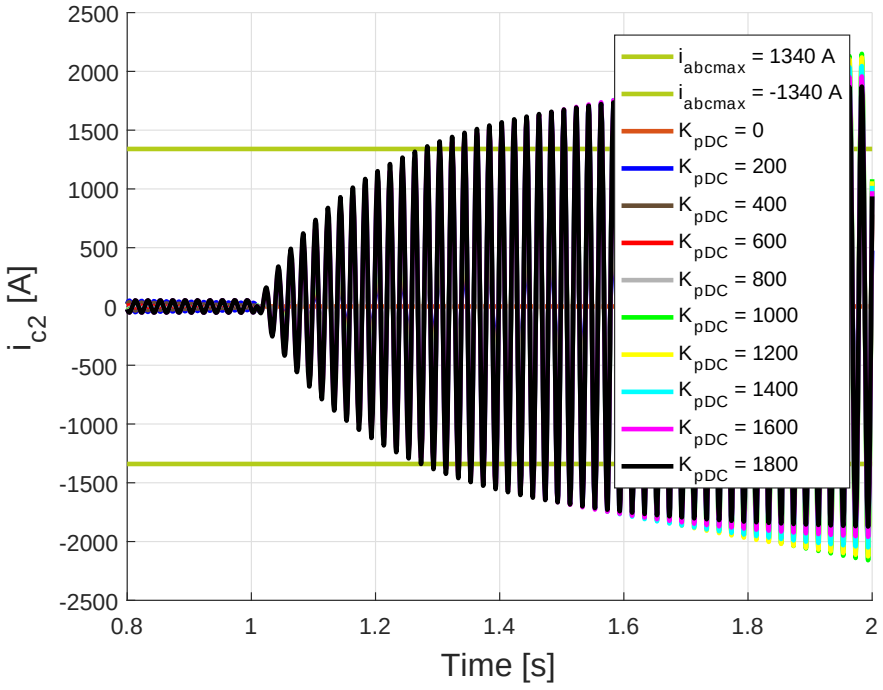

Figure A.29: Current i_{c2} from simulation 1 of Case 1

A.2 Simulation 2

Simulation 2: $K_{pDC} \in [2000, 9000]$ with a step of 700. In total 11 simulations for each electrical magnitude.

A.2.1 Voltages and currents of the multi-terminal HVDC grid

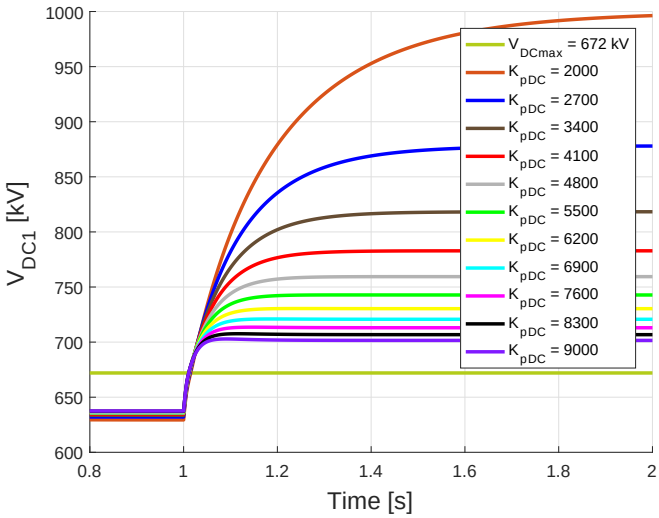

Figure A.30: Voltage V_{DC1} from simulation 2 of Case 1

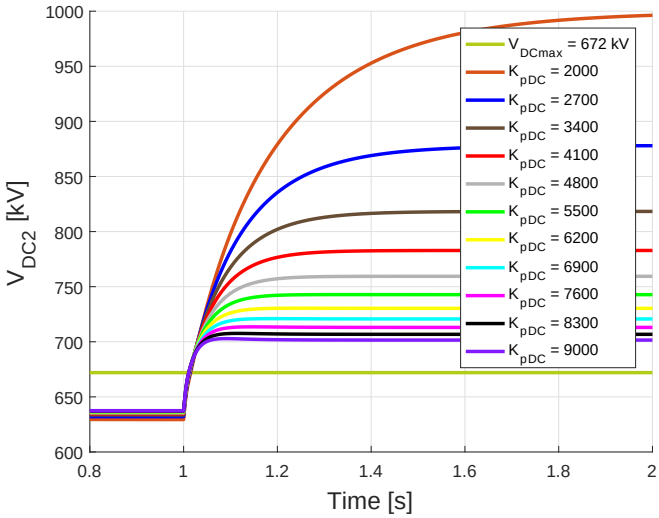

Figure A.31: Voltage V_{DC2} from simulation 2 of Case 1

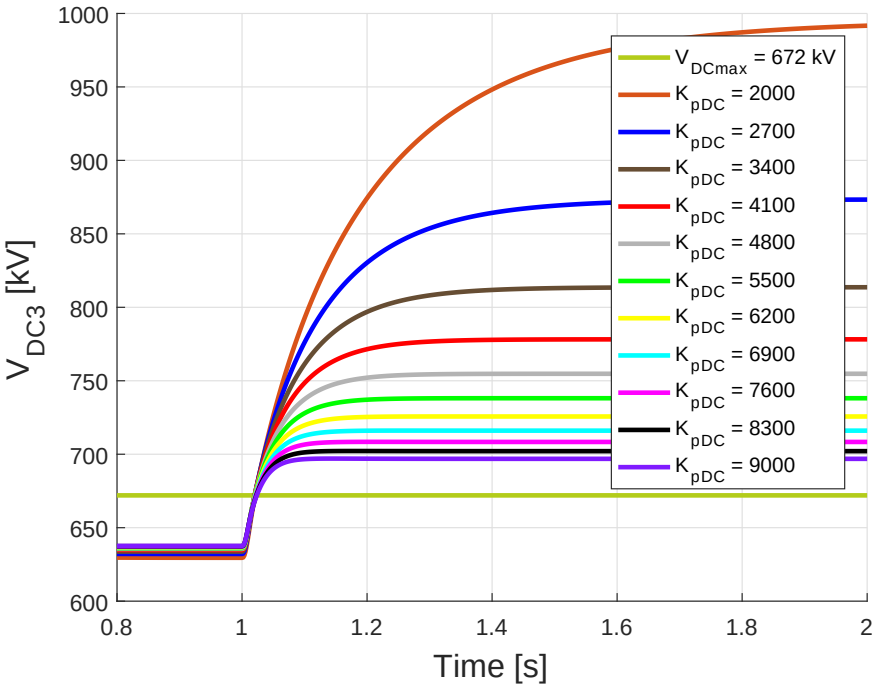

Figure A.32: Voltage V_{DC3} from simulation 2 of Case 1

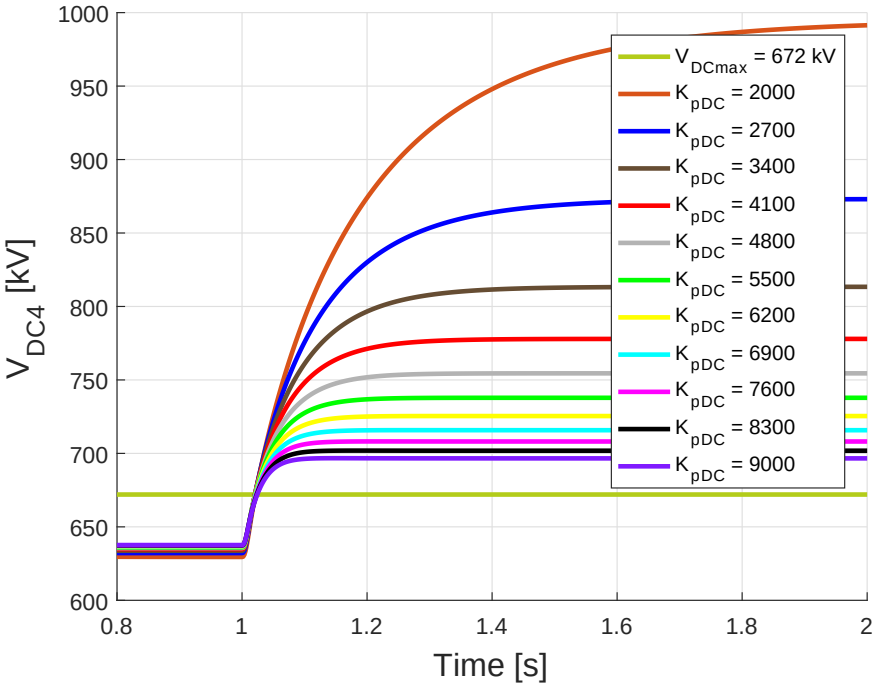

Figure A.33: Voltage V_{DC4} from simulation 2 of Case 1

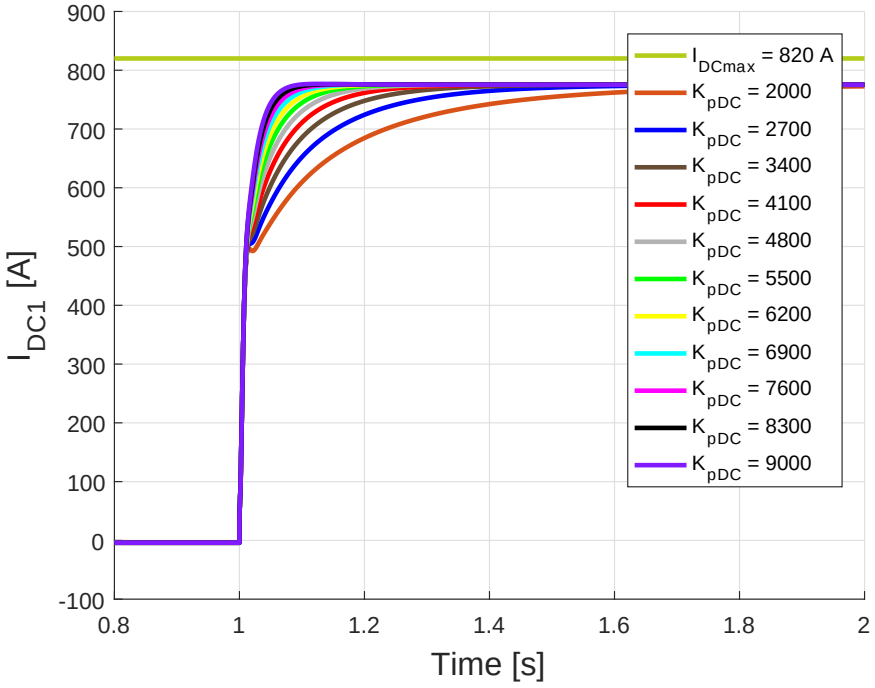

Figure A.34: Current I_{DC1} from simulation 2 of Case 1

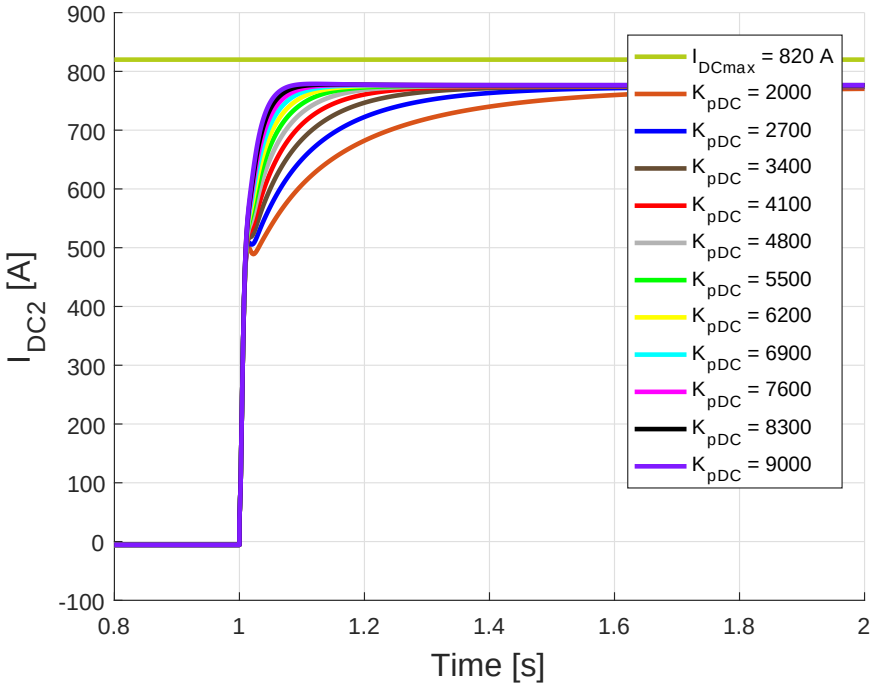

Figure A.35: Current I_{DC2} from simulation 2 of Case 1

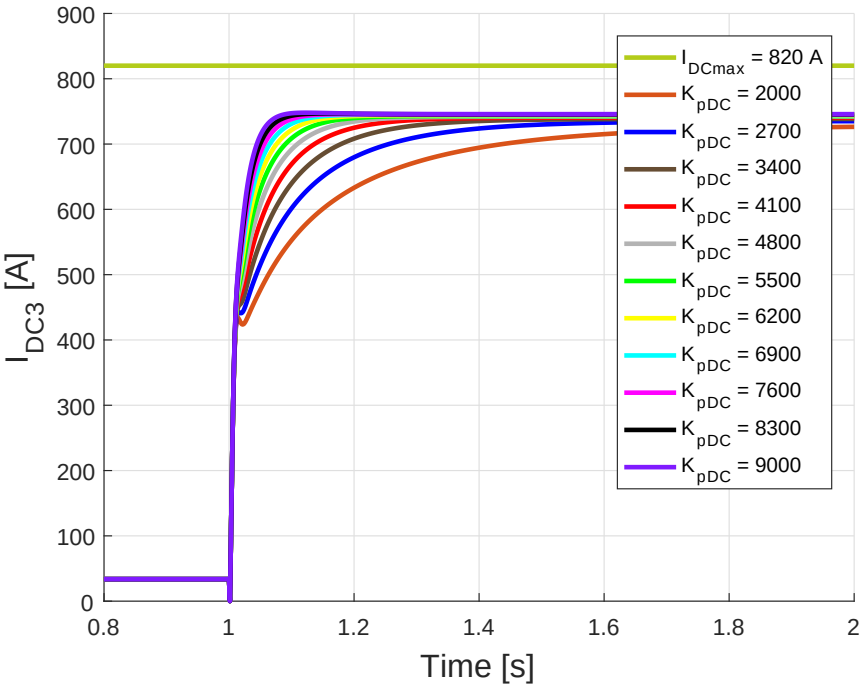

Figure A.36: Current I_{DC3} from simulation 2 of Case 1

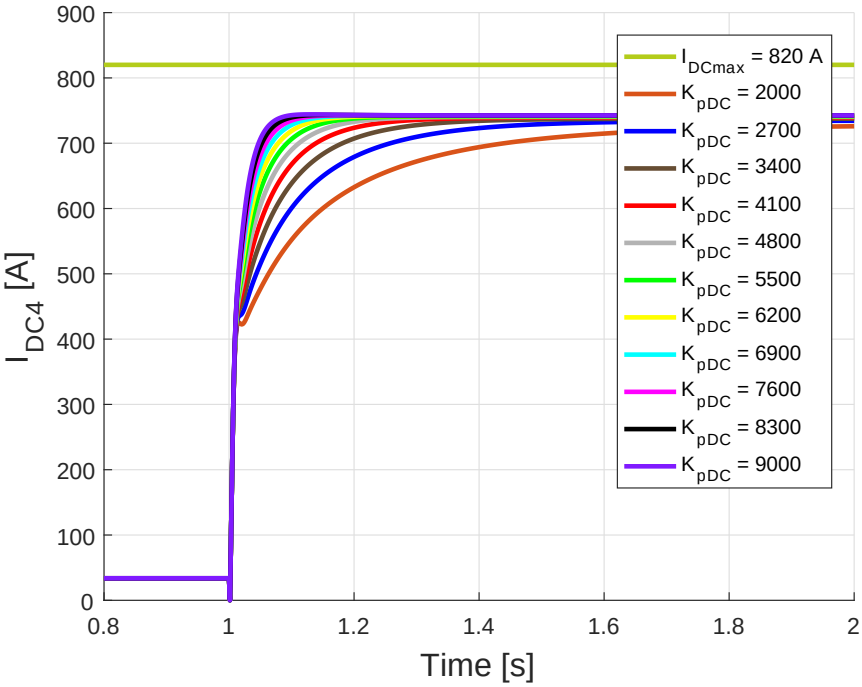

Figure A.37: Current I_{DC4} from simulation 2 of Case 1

A.2.2 Voltages and currents of power converter 1

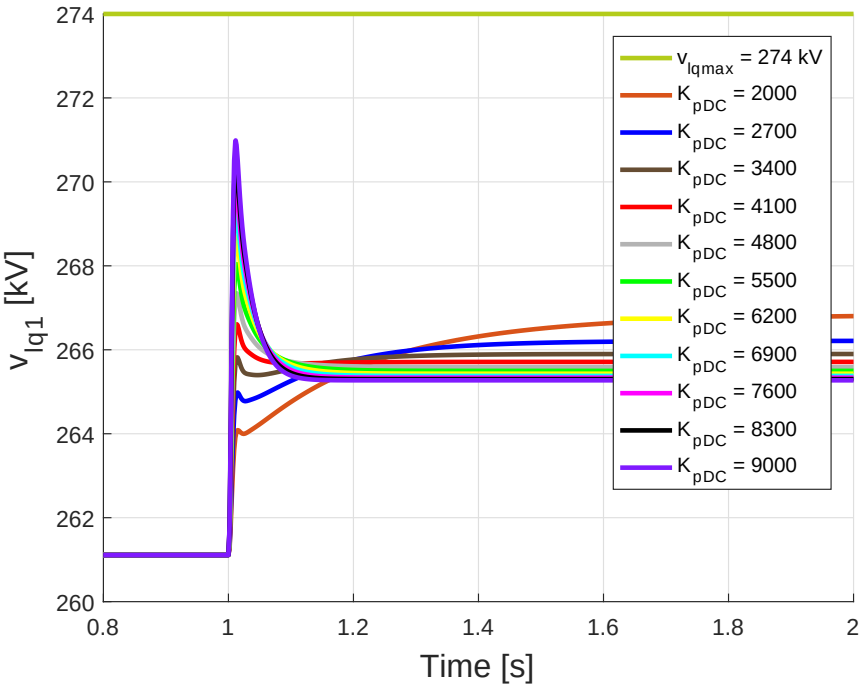

Figure A.38: Voltage v_{lq1} from simulation 2 of Case 1

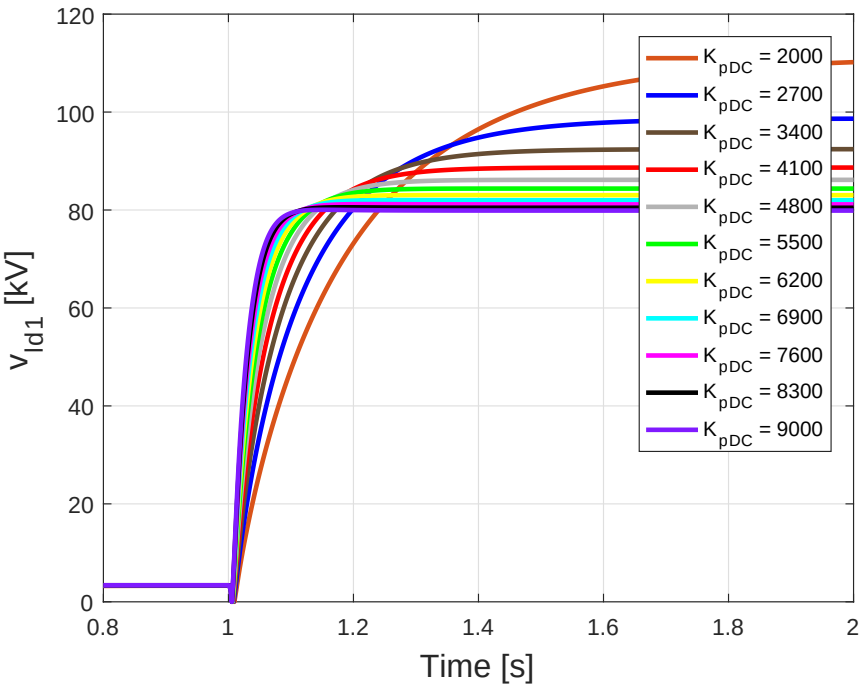

Figure A.39: Voltage v_{ld1} from simulation 2 of Case 1

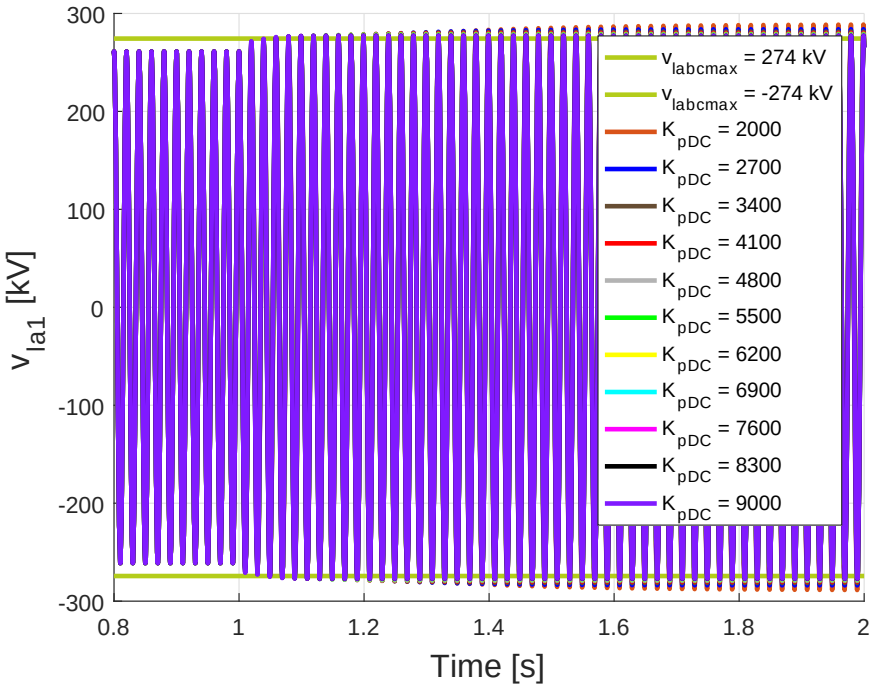

Figure A.40: Voltage v_{la1} from simulation 2 of Case 1

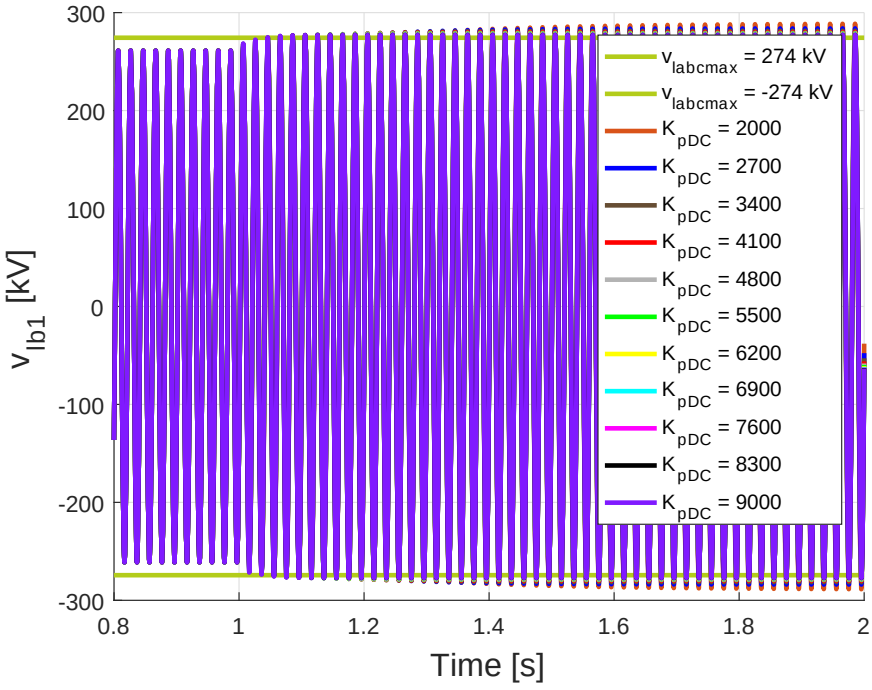

Figure A.41: Voltage v_{lb1} from simulation 2 of Case 1

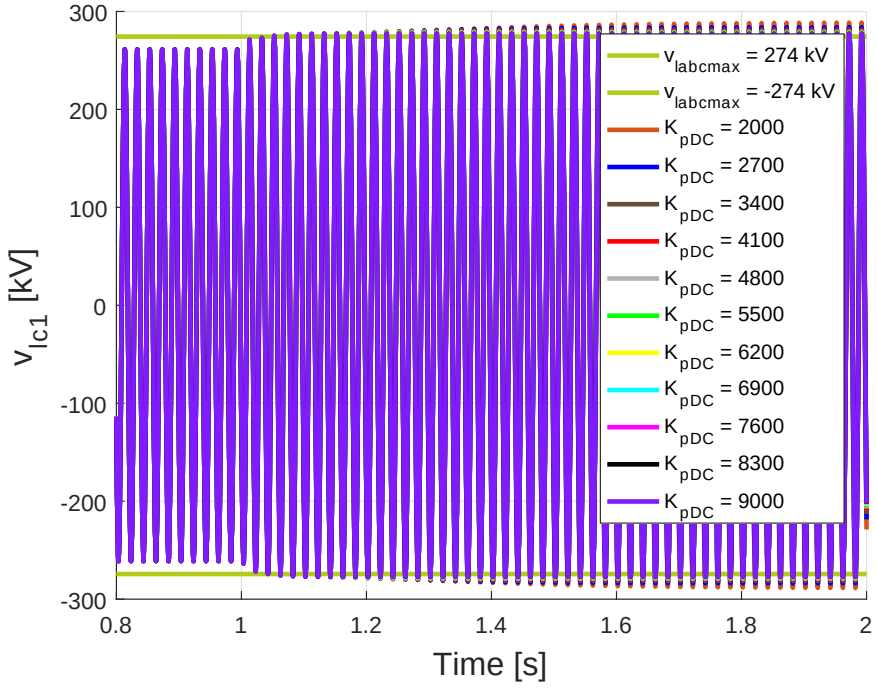

Figure A.42: Voltage v_{lc1} from simulation 2 of Case 1

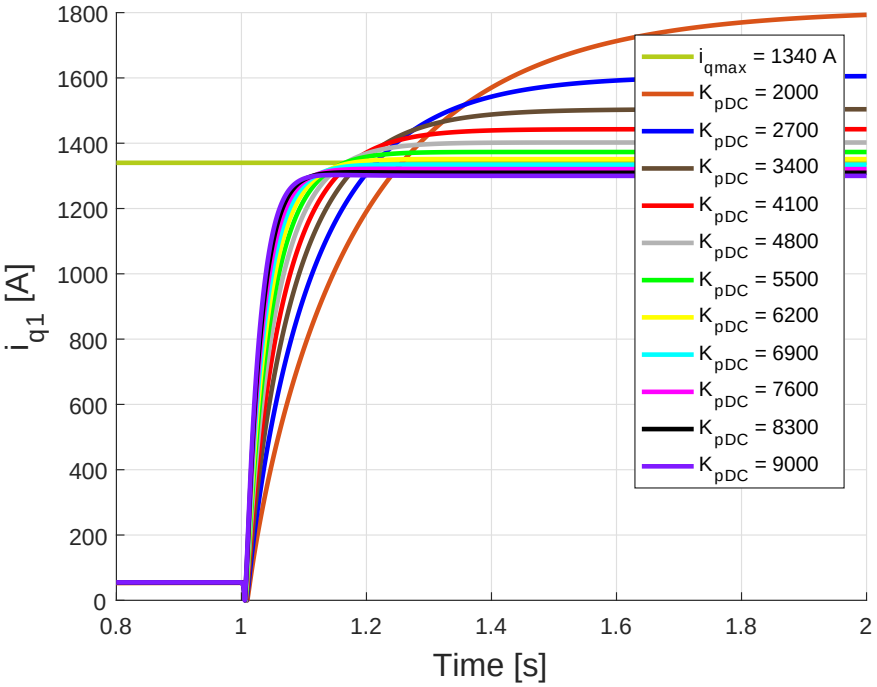

Figure A.43: Current i_{q1} from simulation 2 of Case 1

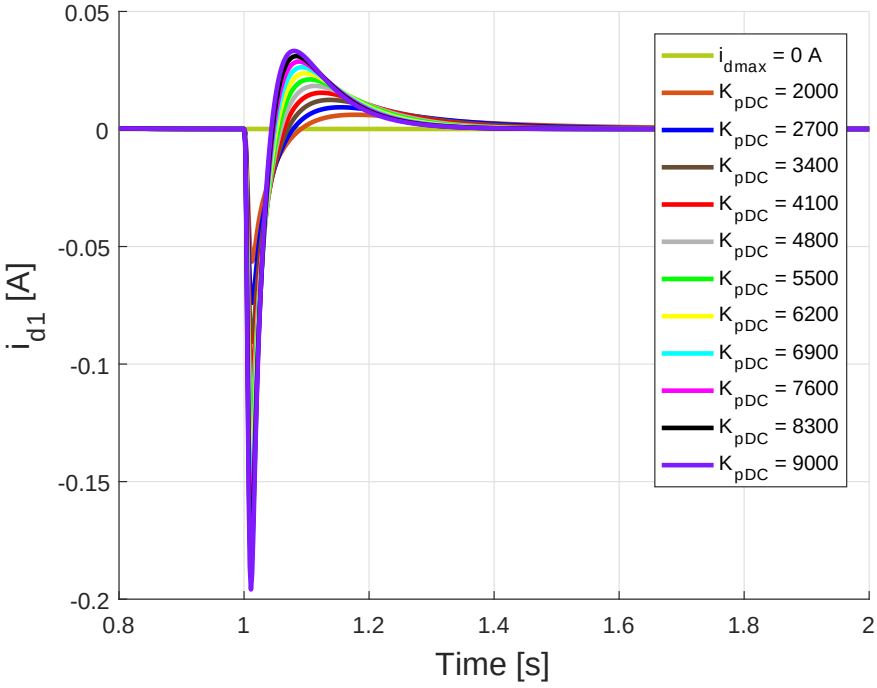

Figure A.44: Current i_{d1} from simulation 2 of Case 1

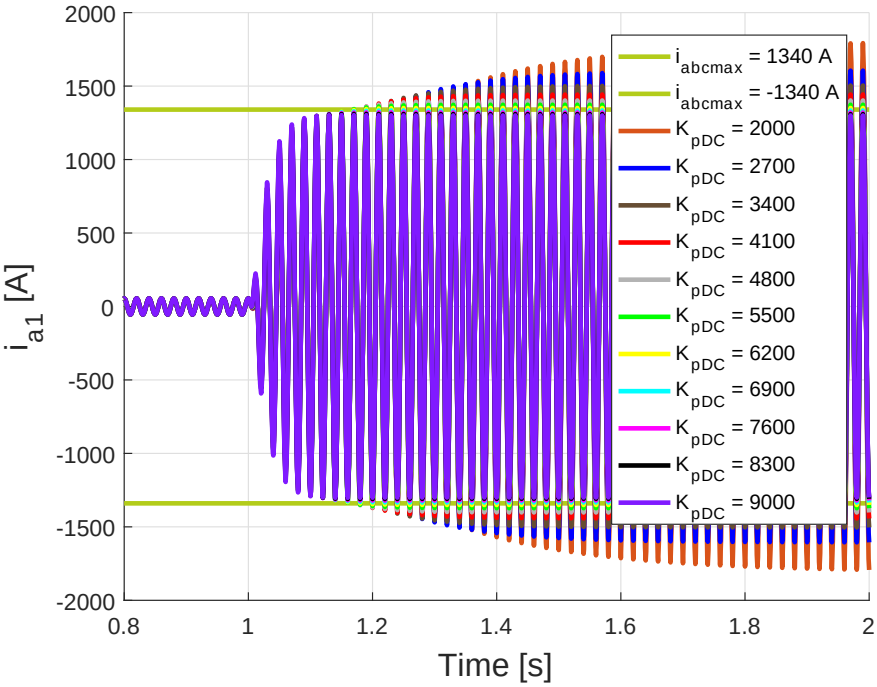

Figure A.45: Current i_{a1} from simulation 2 of Case 1

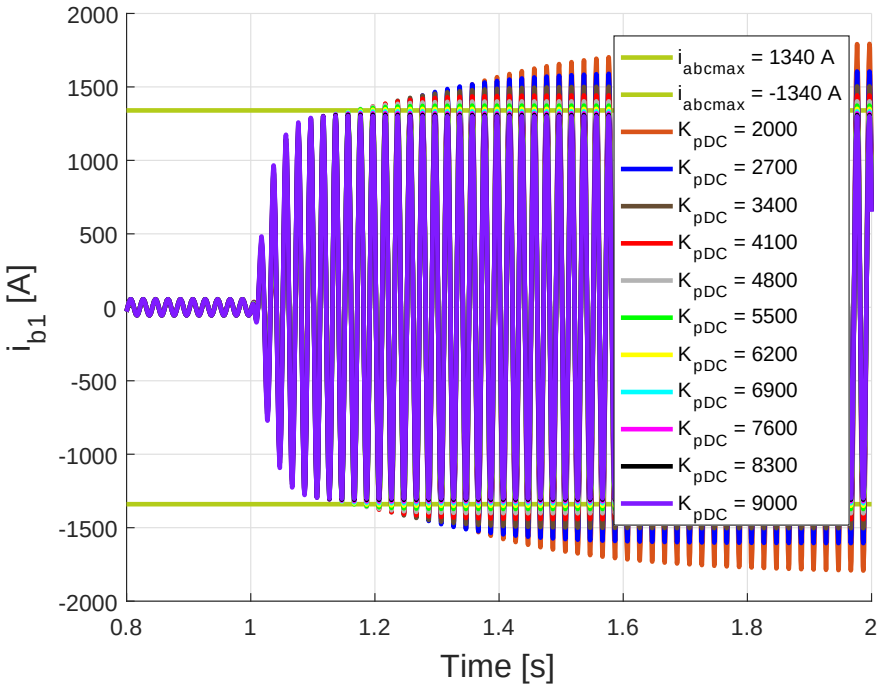

Figure A.46: Current i_{b1} from simulation 2 of Case 1

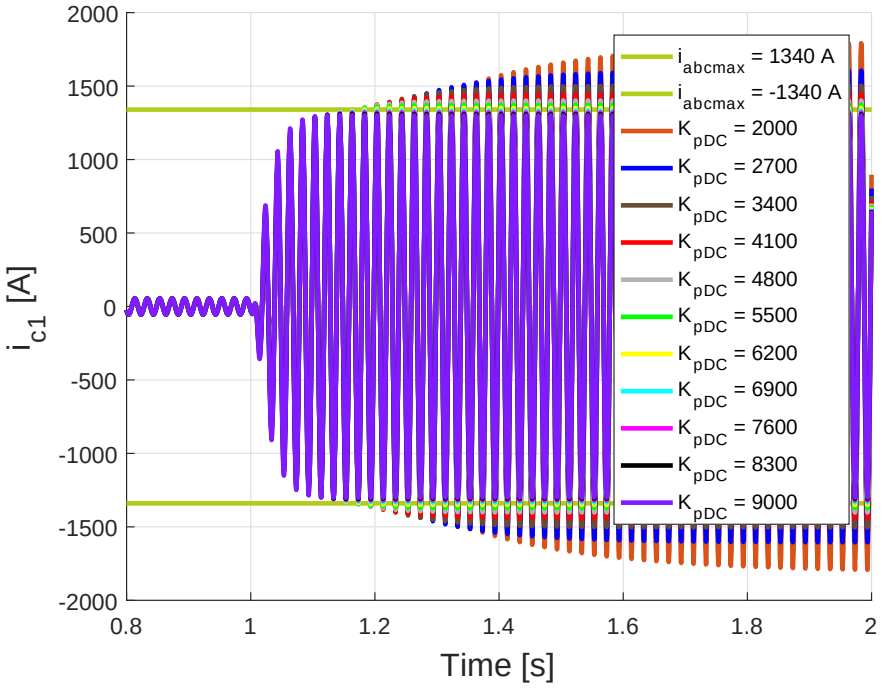

Figure A.47: Current i_{c1} from simulation 2 of Case 1

A.2.3 Voltages and currents of power converter 2

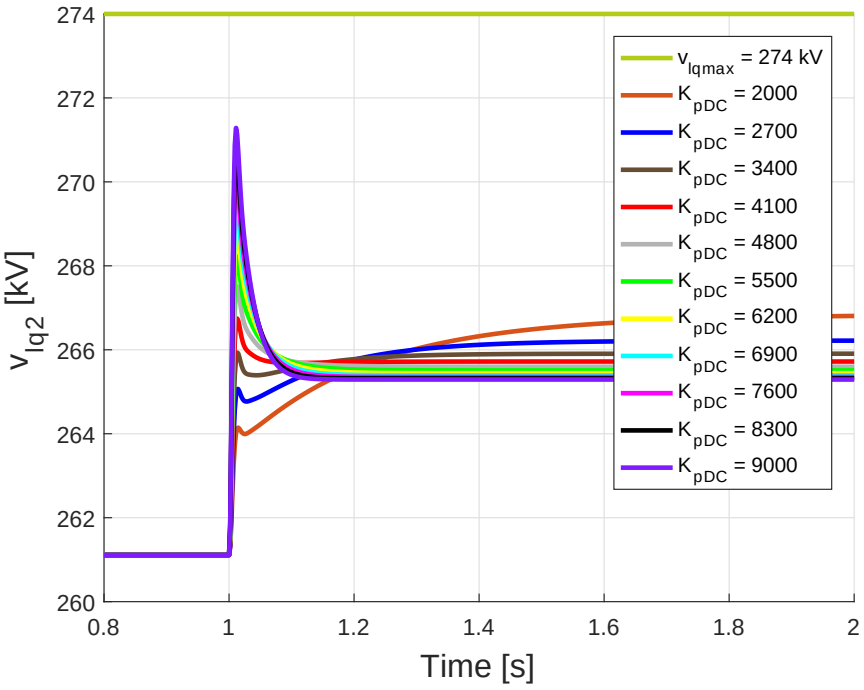

Figure A.48: Voltage v_{lq2} from simulation 2 of Case 1

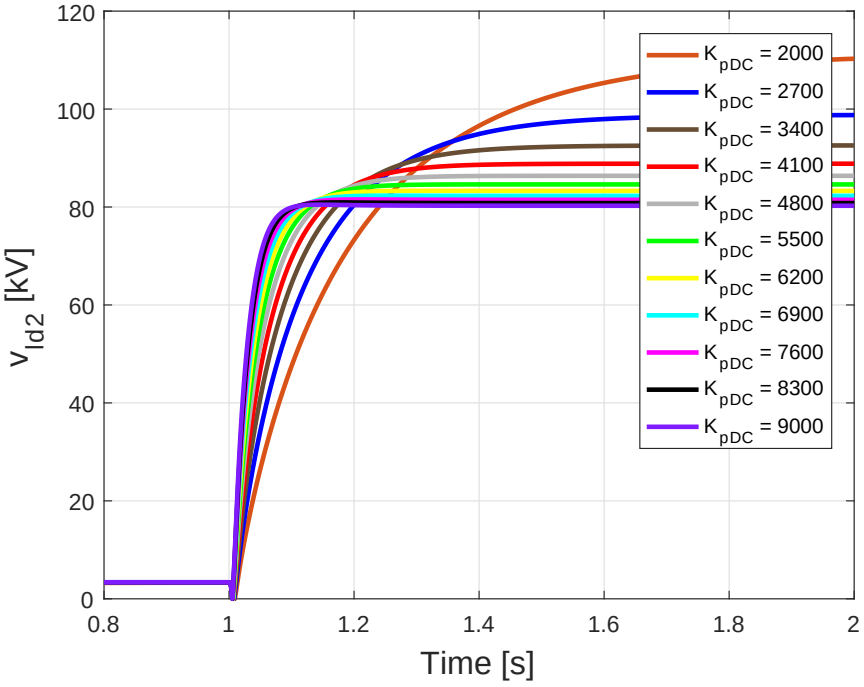

Figure A.49: Voltage v_{ld2} from simulation 2 of Case 1

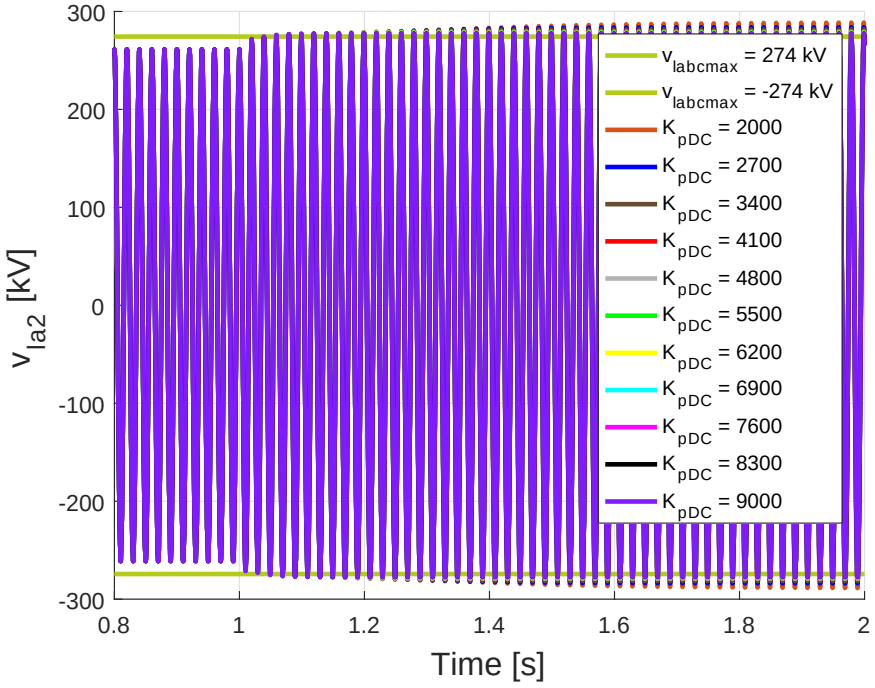

Figure A.50: Voltage v_{la2} from simulation 2 of Case 1

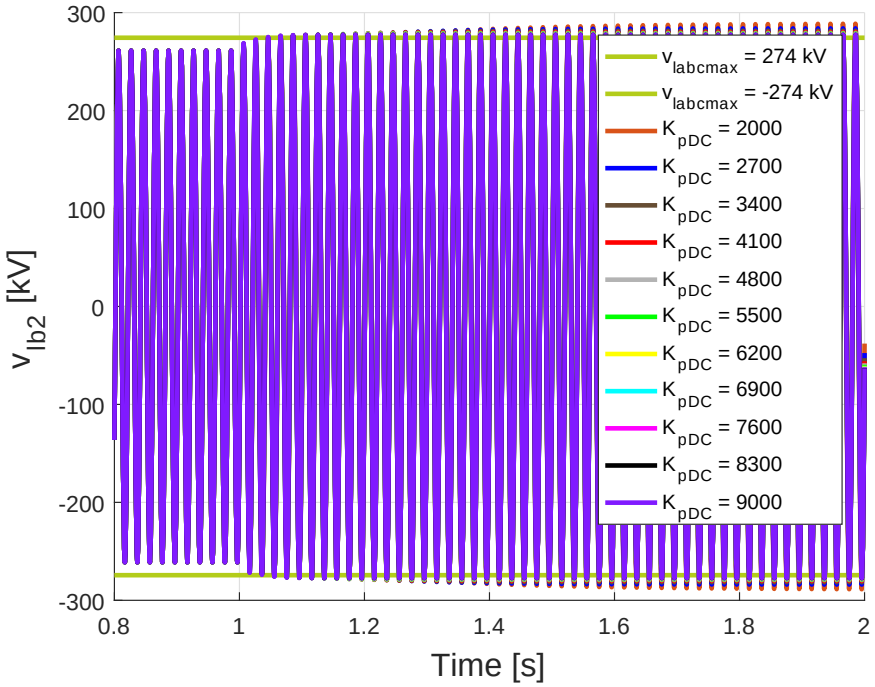

Figure A.51: Voltage v_{lb2} from simulation 2 of Case 1

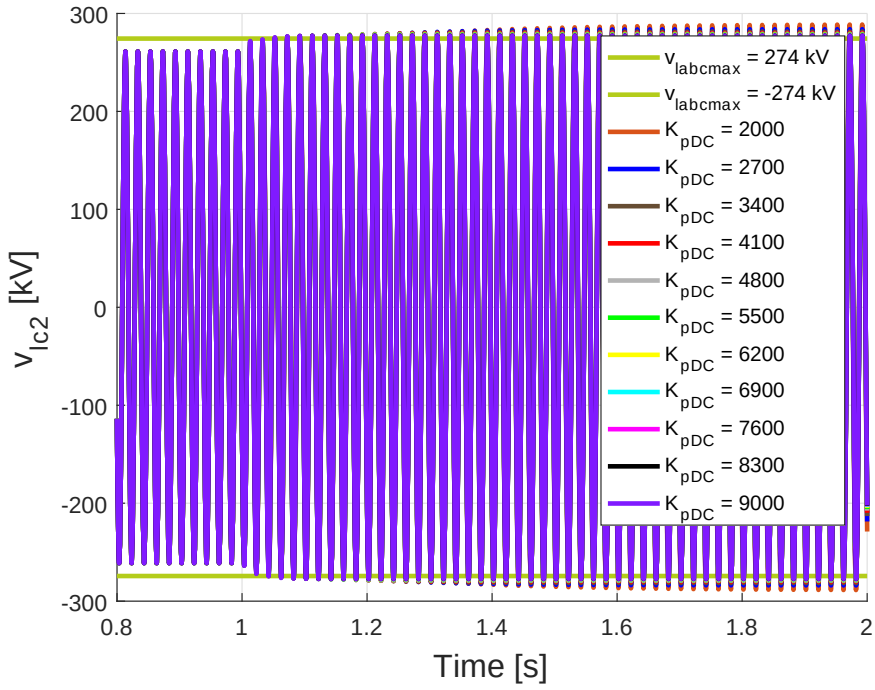

Figure A.52: Voltage v_{lc2} from simulation 2 of Case 1

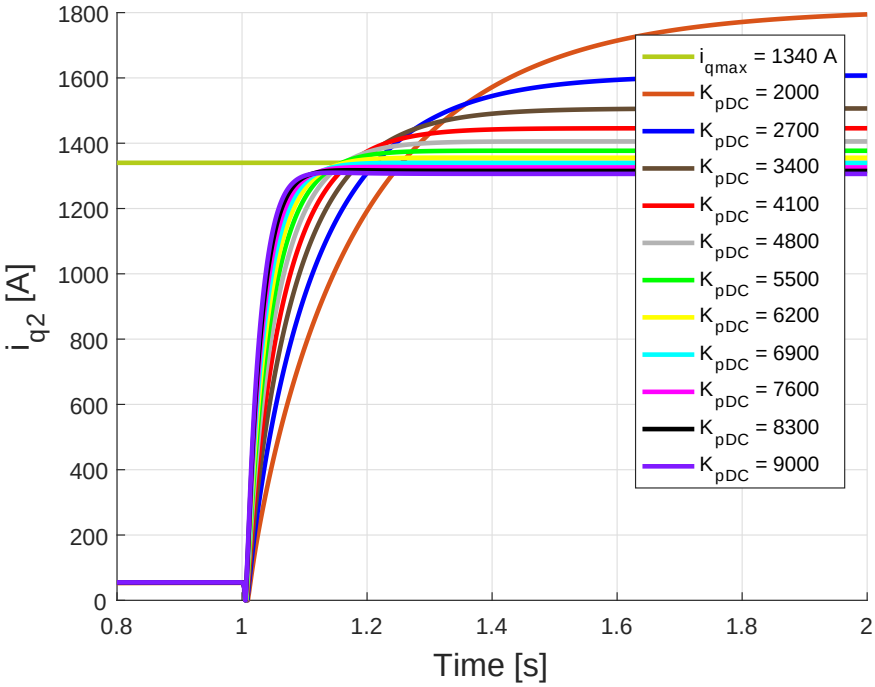

Figure A.53: Current i_{q2} from simulation 2 of Case 1

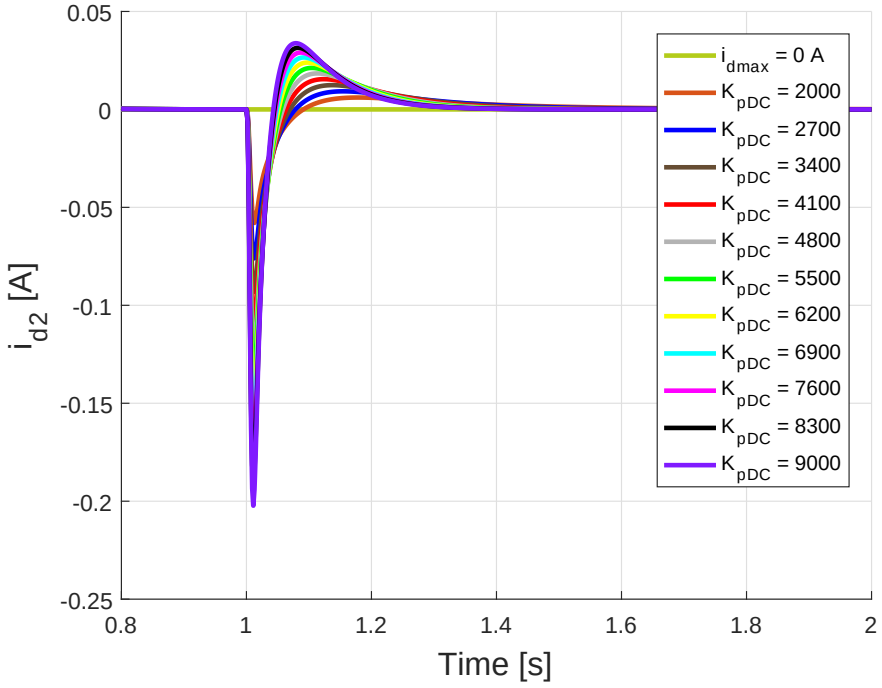

Figure A.54: Current i_{d2} from simulation 2 of Case 1

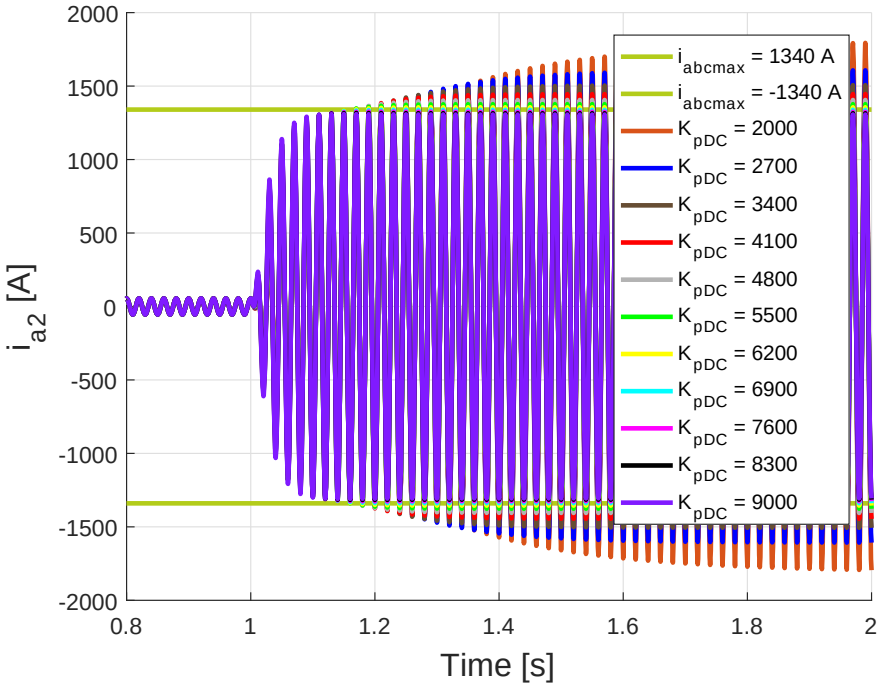

Figure A.55: Current i_{a2} from simulation 2 of Case 1

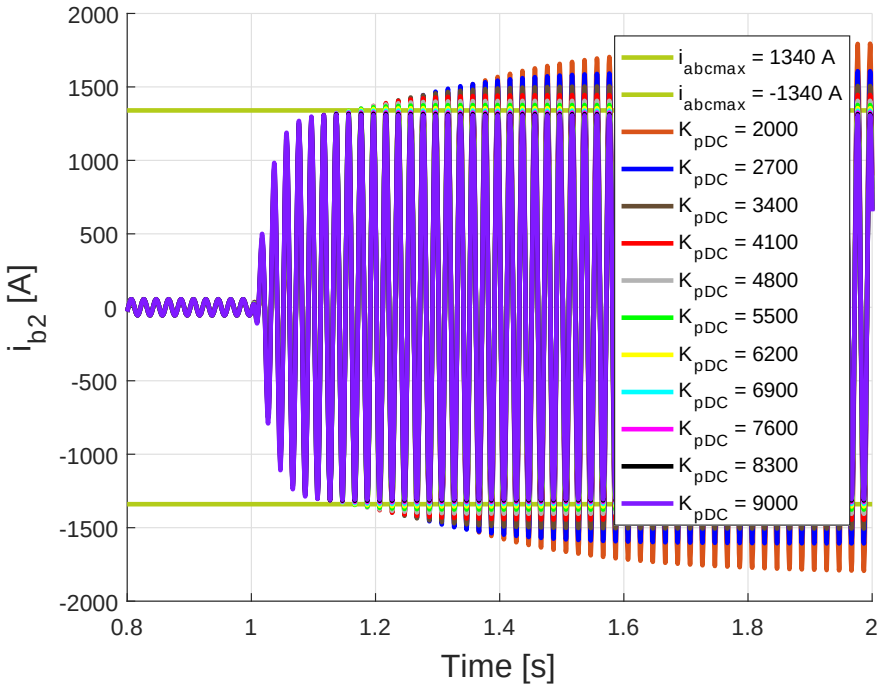

Figure A.56: Current i_{b2} from simulation 2 of Case 1

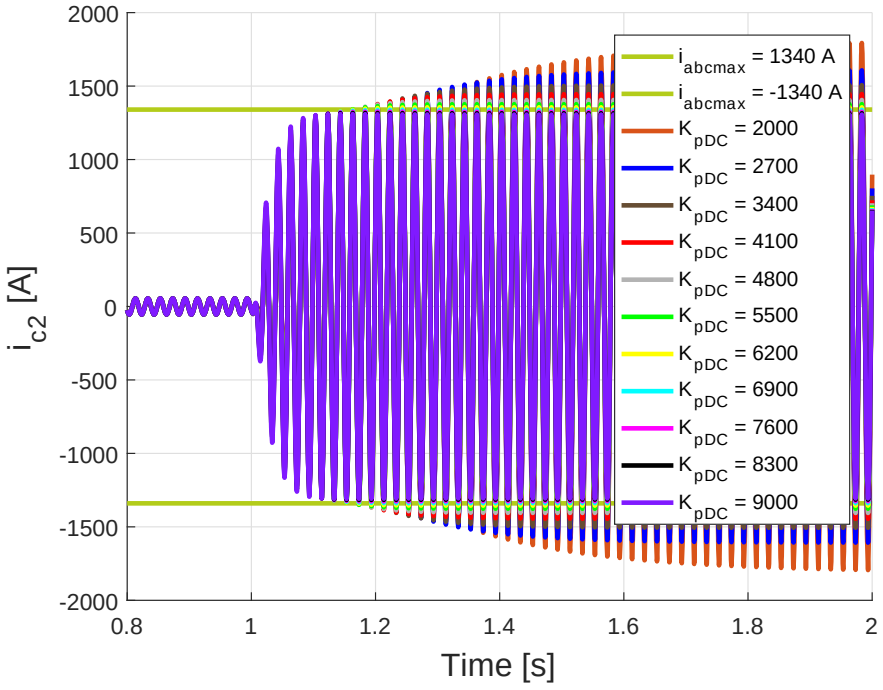

Figure A.57: Current i_{c2} from simulation 2 of Case 1

A.3 Simulation 3

Simulation 3: $K_{pDC} \in [10000, 50000]$ with a step of 5000. In total 9 simulations for each electrical magnitude.

A.3.1 Voltages and currents of the multi-terminal HVDC grid

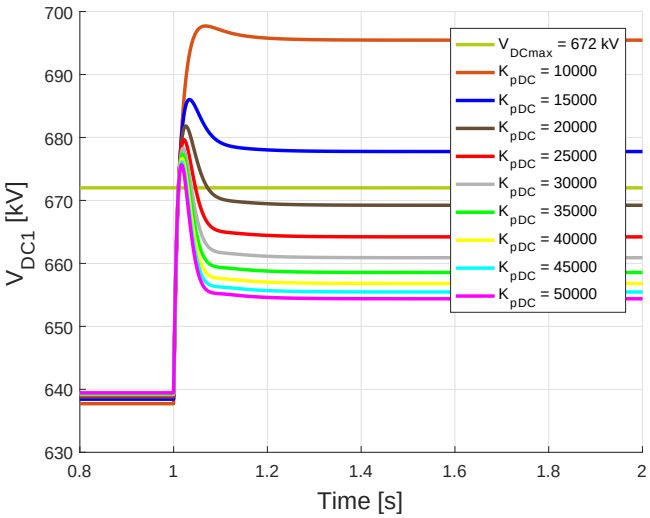

Figure A.58: Voltage V_{DC1} from simulation 3 of Case 1

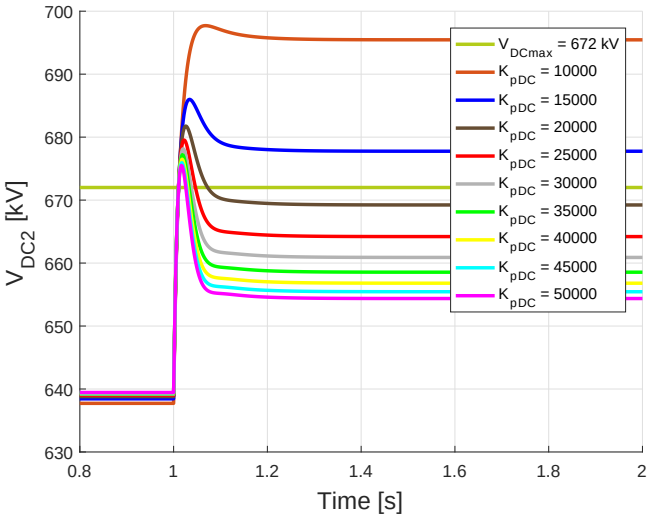

Figure A.59: Voltage V_{DC2} from simulation 3 of Case 1

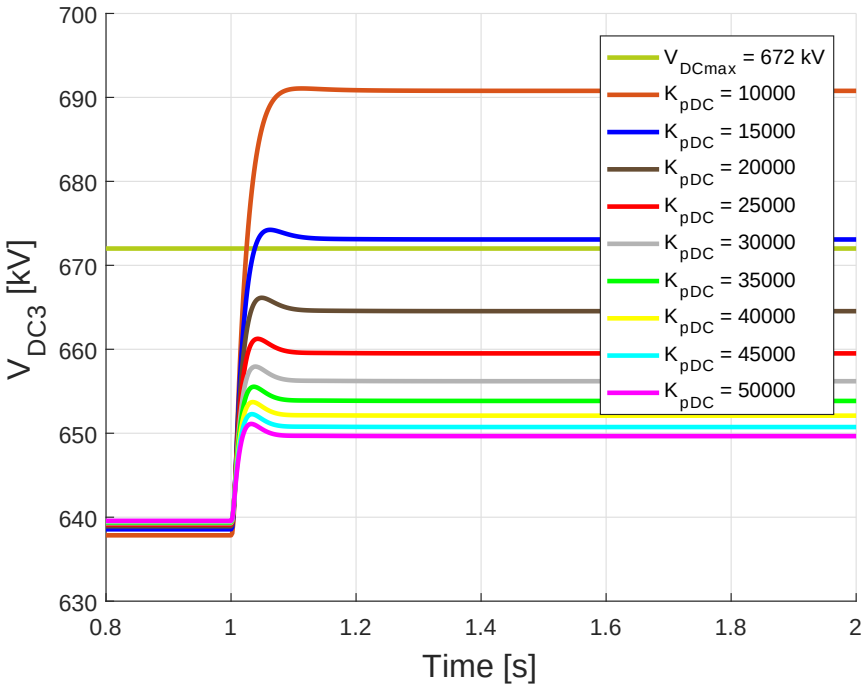

Figure A.60: Voltage V_{DC3} from simulation 3 of Case 1

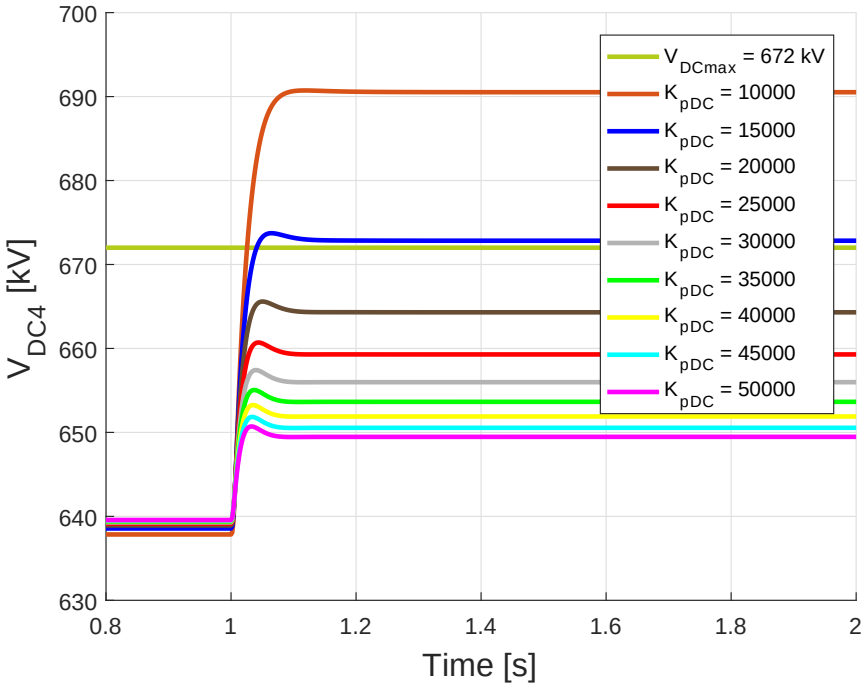

Figure A.61: Voltage V_{DC4} from simulation 3 of Case 1

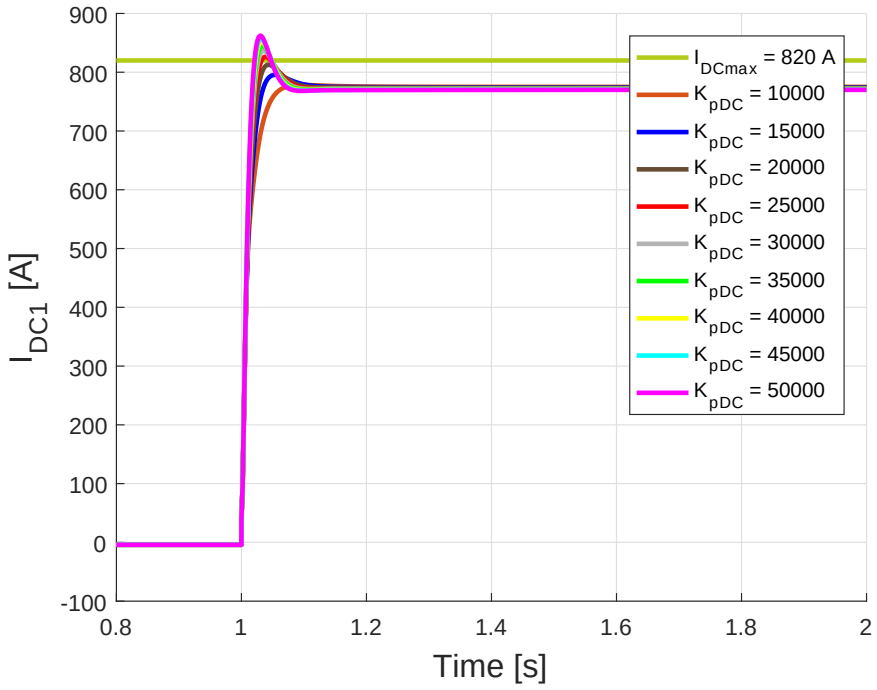

Figure A.62: Current I_{DC1} from simulation 3 of Case 1

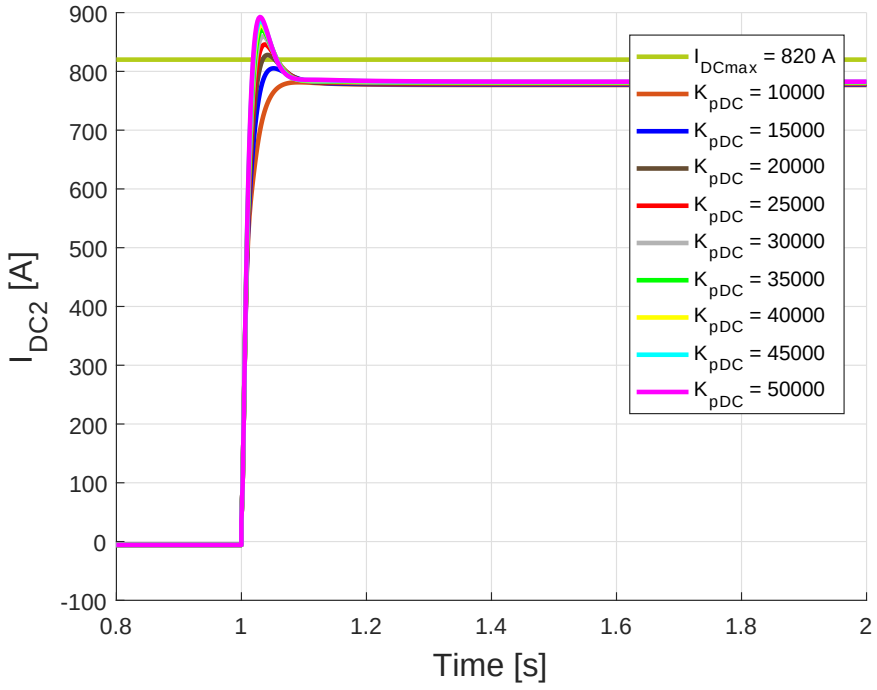

Figure A.63: Current I_{DC2} from simulation 3 of Case 1

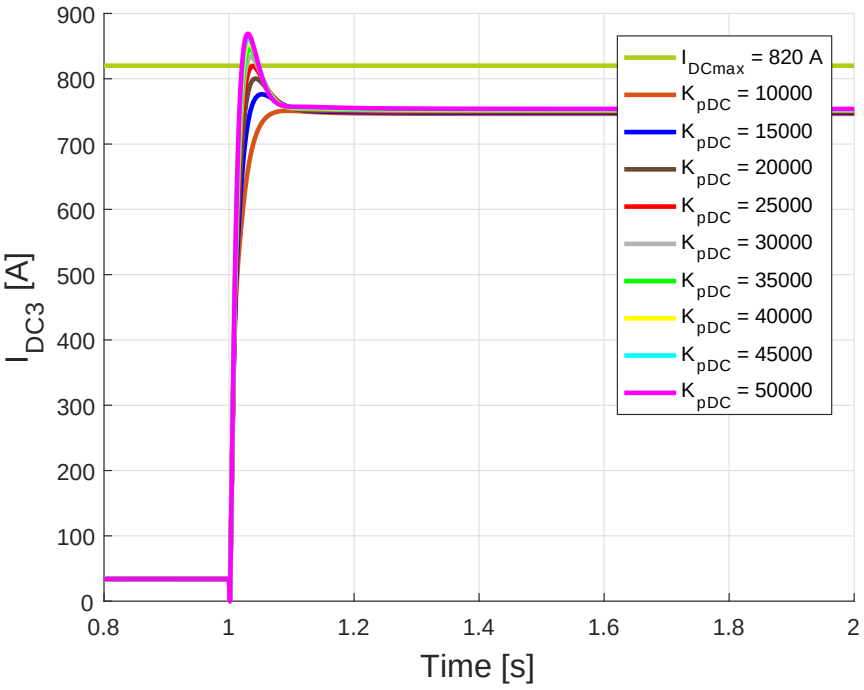

Figure A.64: Current I_{DC3} from simulation 3 of Case 1

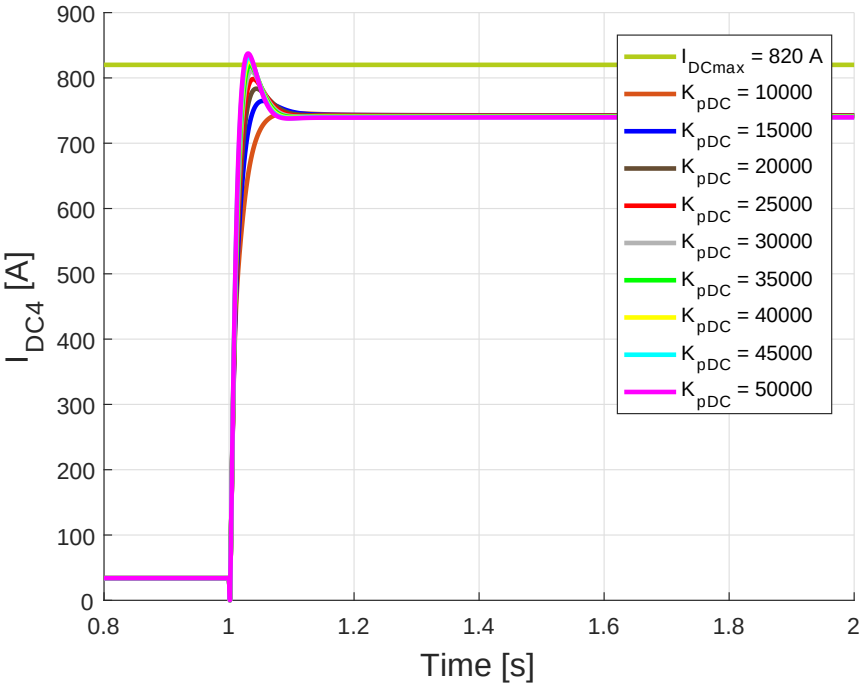

Figure A.65: Current I_{DC4} from simulation 3 of Case 1

A.3.2 Voltages and currents of power converter 1

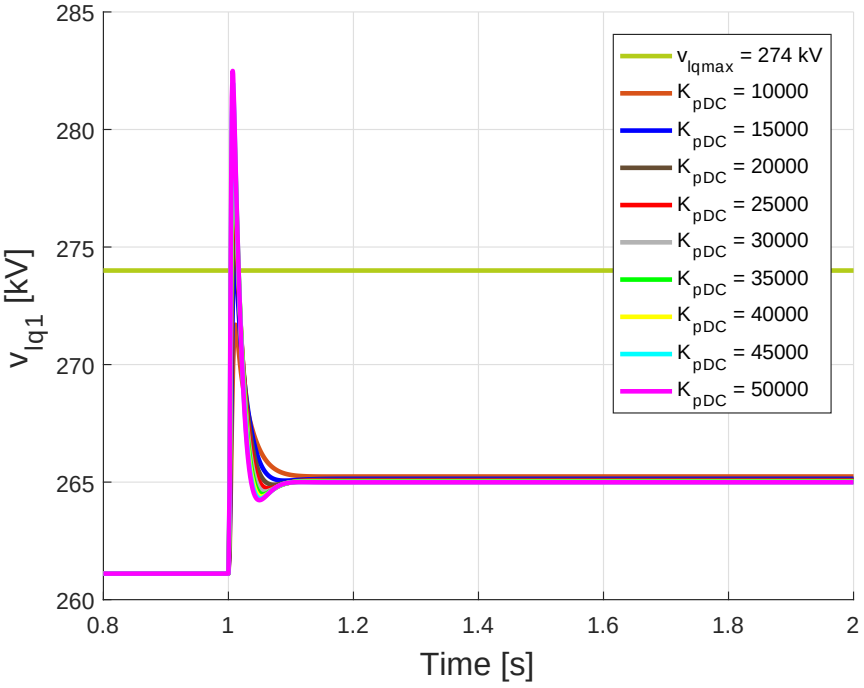

Figure A.66: Voltage v_{lq1} from simulation 3 of Case 1

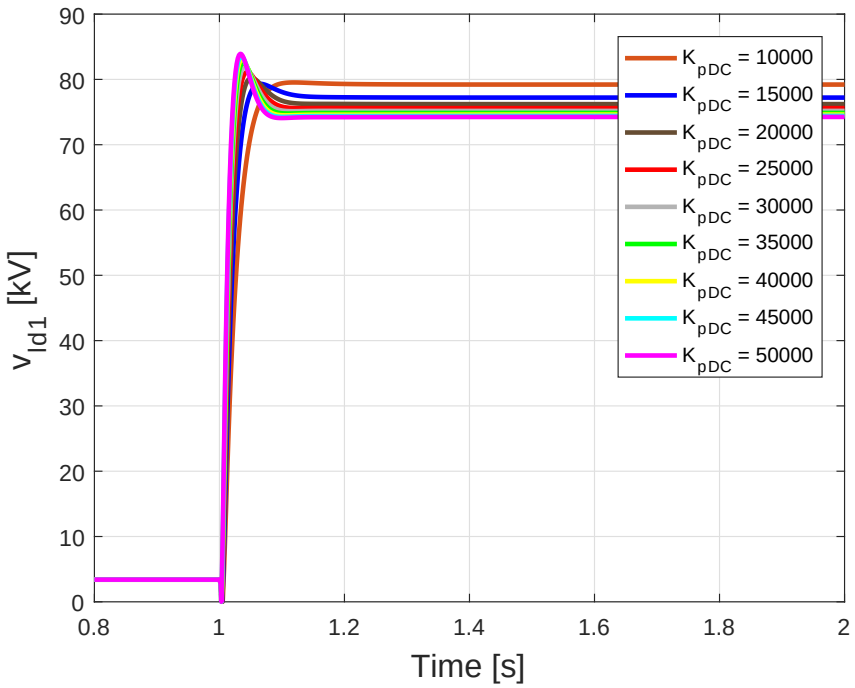

Figure A.67: Voltage v_{ld1} from simulation 3 of Case 1

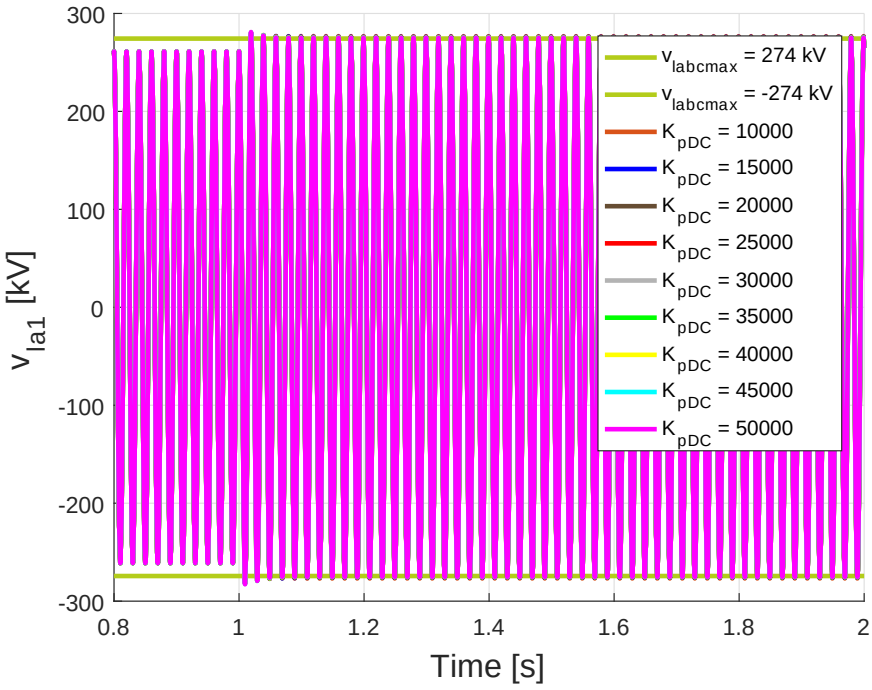

Figure A.68: Voltage v_{la1} from simulation 3 of Case 1

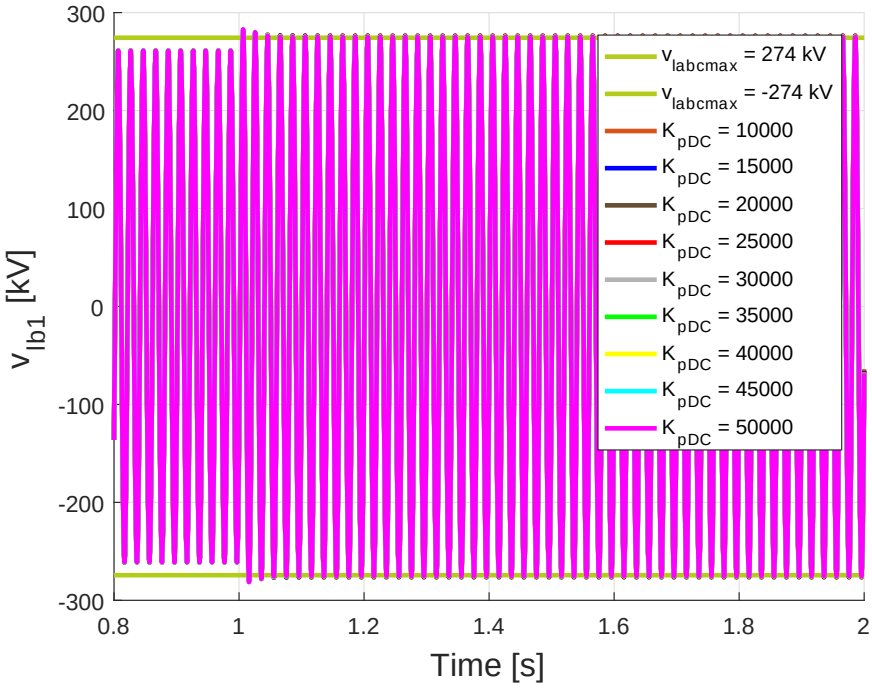

Figure A.69: Voltage v_{lb1} from simulation 3 of Case 1

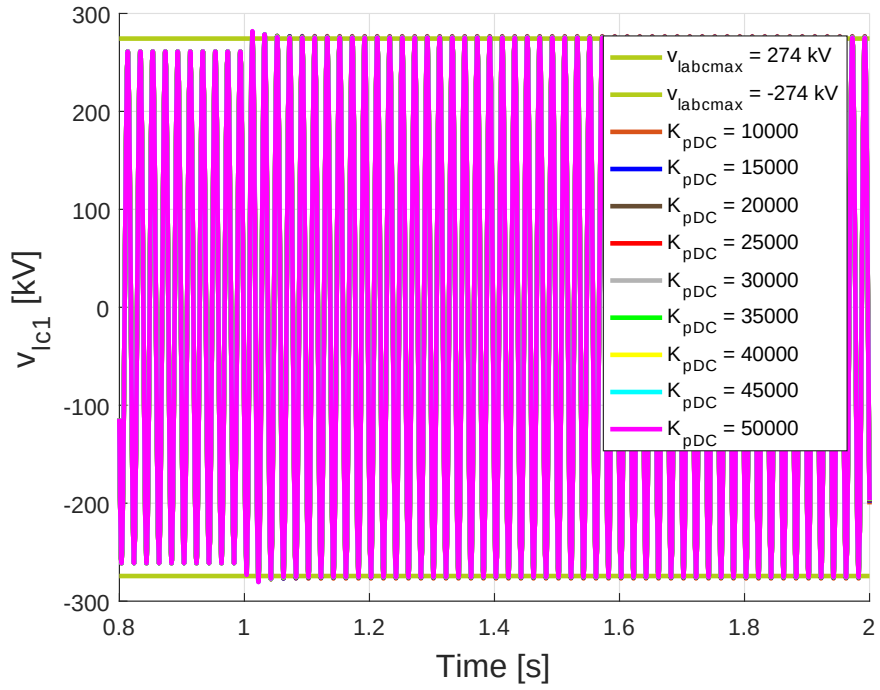

Figure A.70: Voltage v_{lc1} from simulation 3 of Case 1

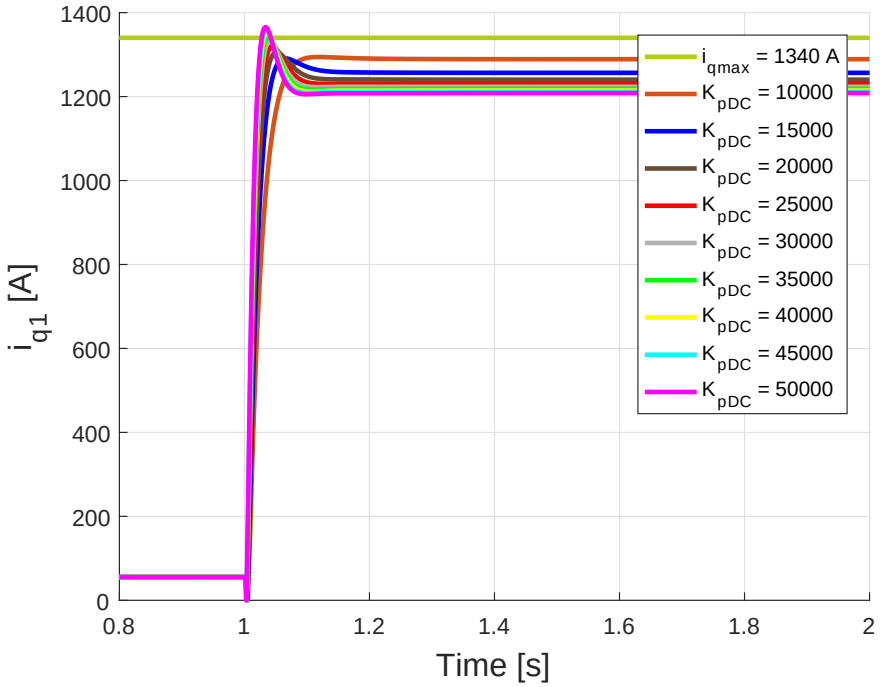

Figure A.71: Current i_{q1} from simulation 3 of Case 1

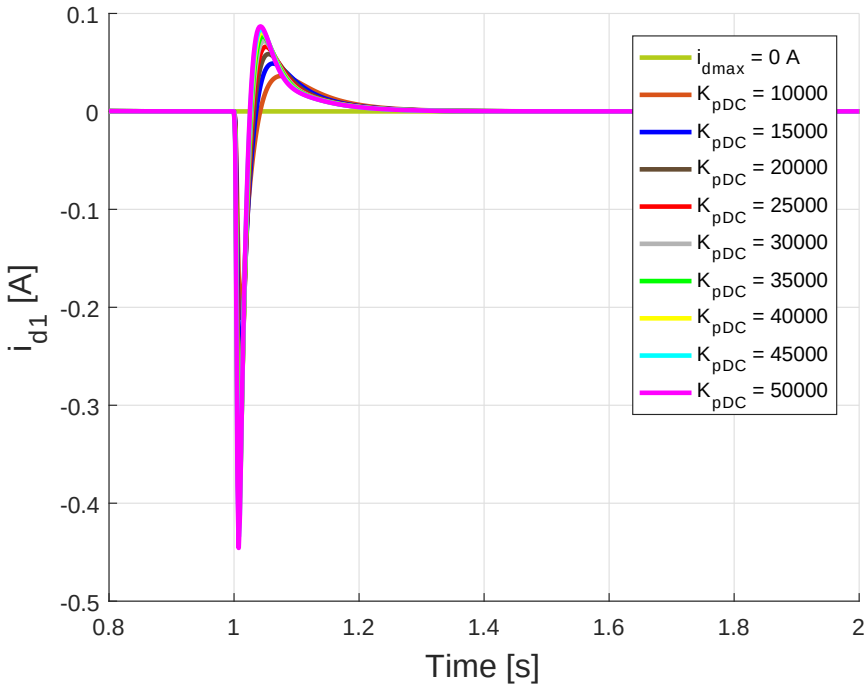

Figure A.72: Current i_{d1} from simulation 3 of Case 1

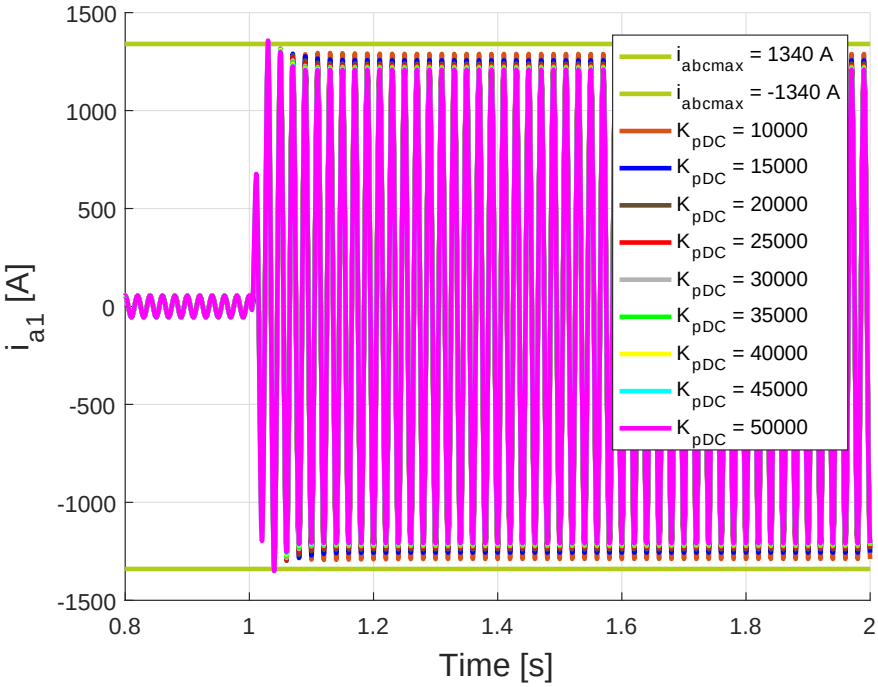

Figure A.73: Current i_{a1} from simulation 3 of Case 1

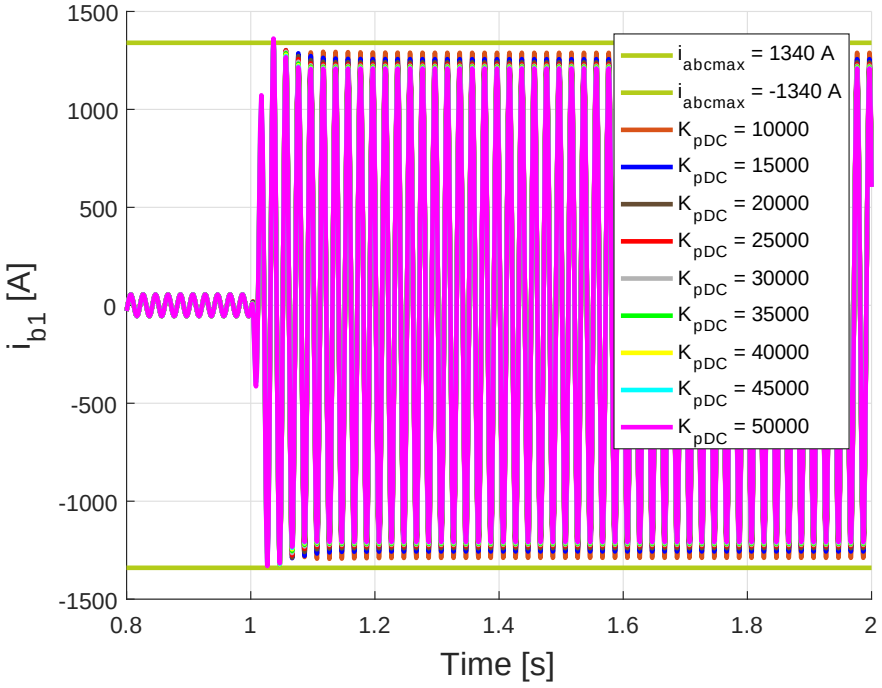

Figure A.74: Current i_{b1} from simulation 3 of Case 1

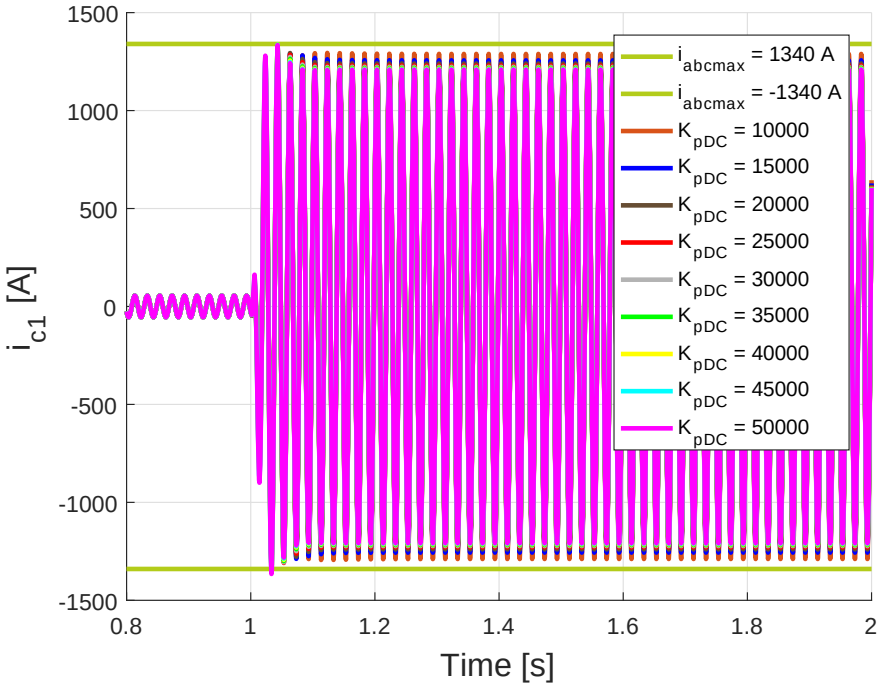

Figure A.75: Current i_{c1} from simulation 3 of Case 1

A.3.3 Voltages and currents of power converter 2

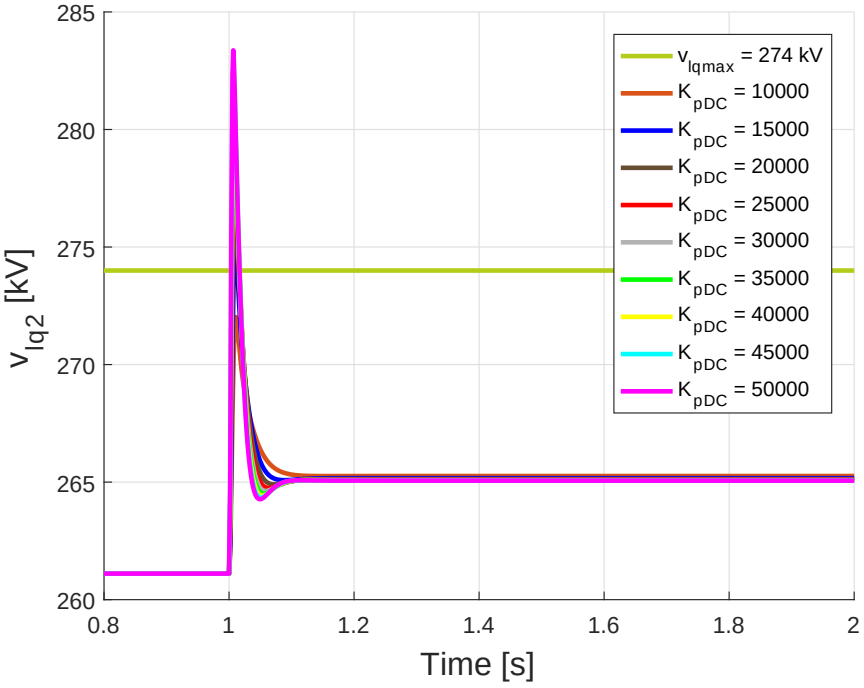

Figure A.76: Voltage v_{lq2} from simulation 3 of Case 1

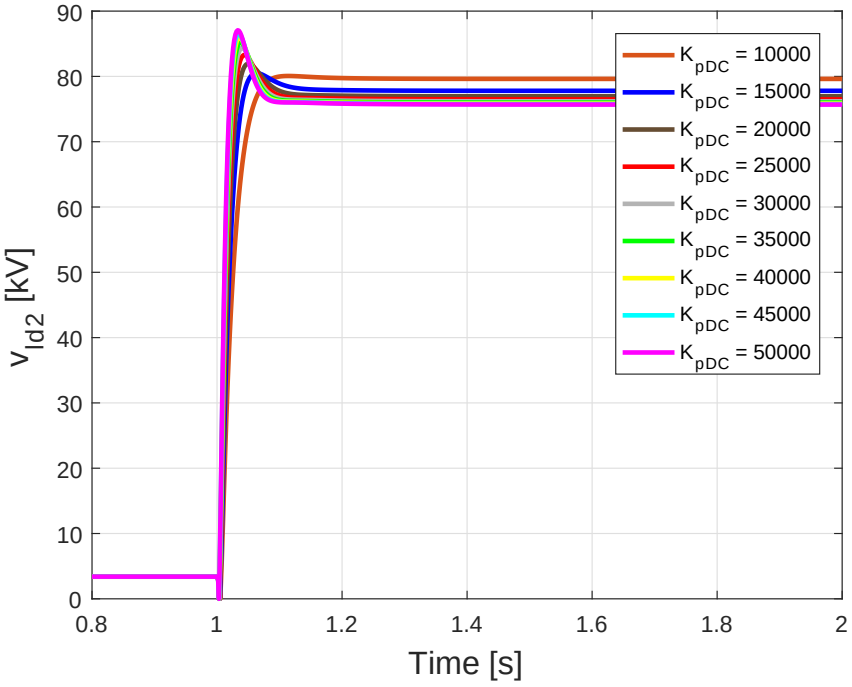

Figure A.77: Voltage v_{ld2} from simulation 3 of Case 1

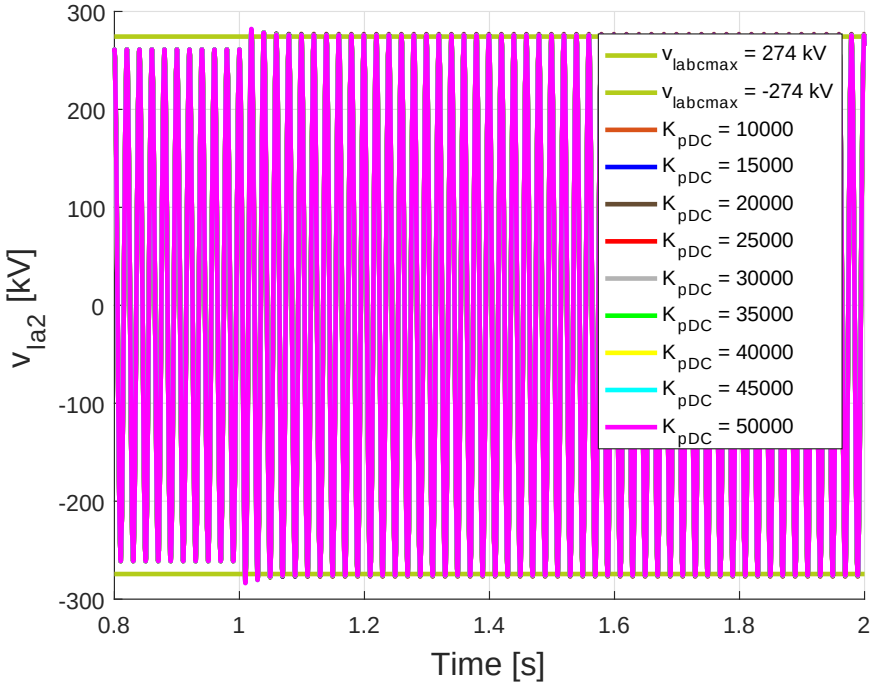

Figure A.78: Voltage v_{la2} from simulation 3 of Case 1

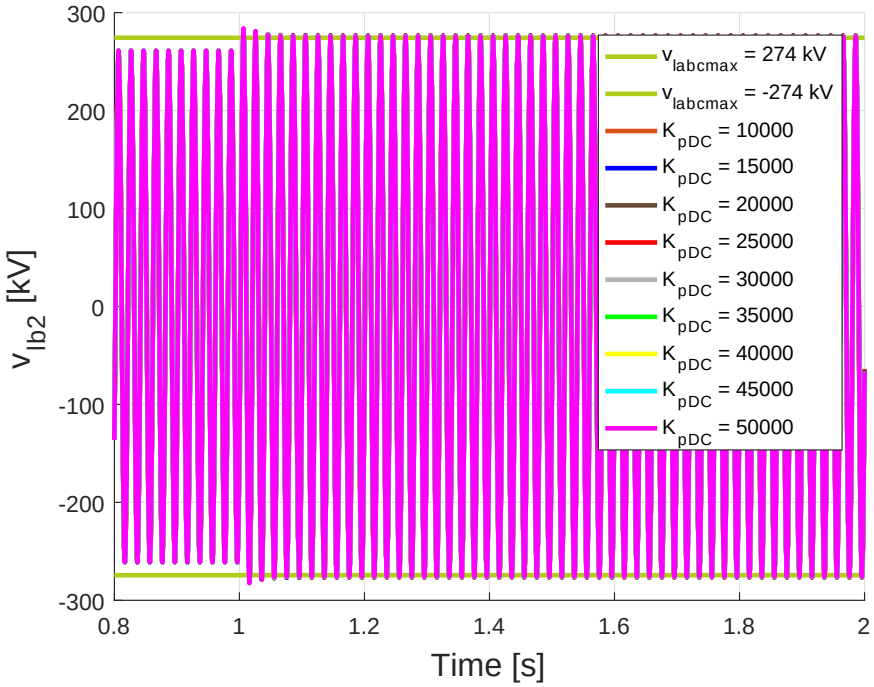

Figure A.79: Voltage v_{lb2} from simulation 3 of Case 1

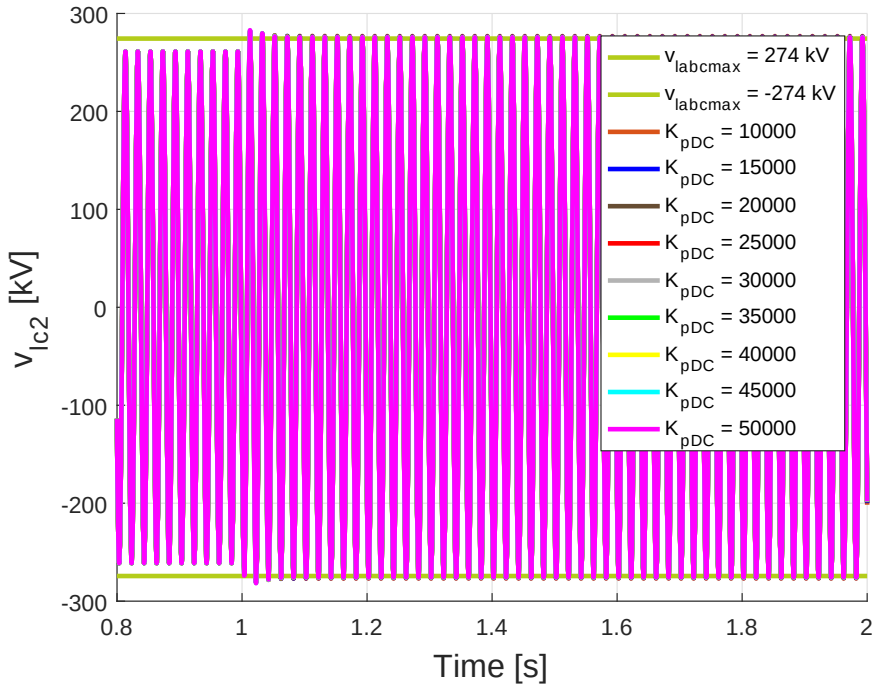

Figure A.80: Voltage v_{lc2} from simulation 3 of Case 1

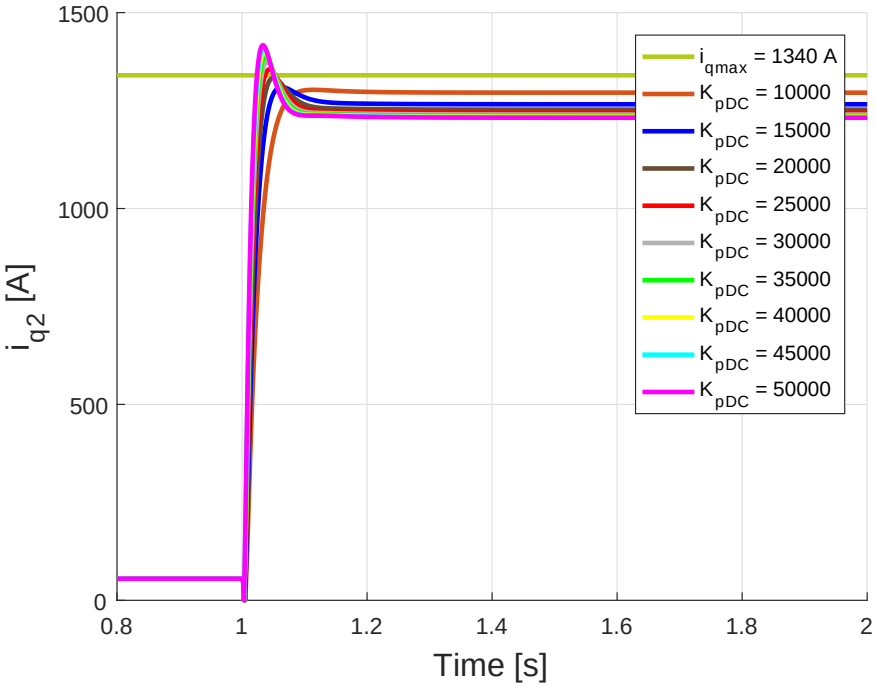

Figure A.81: Current i_{q2} from simulation 3 of Case 1

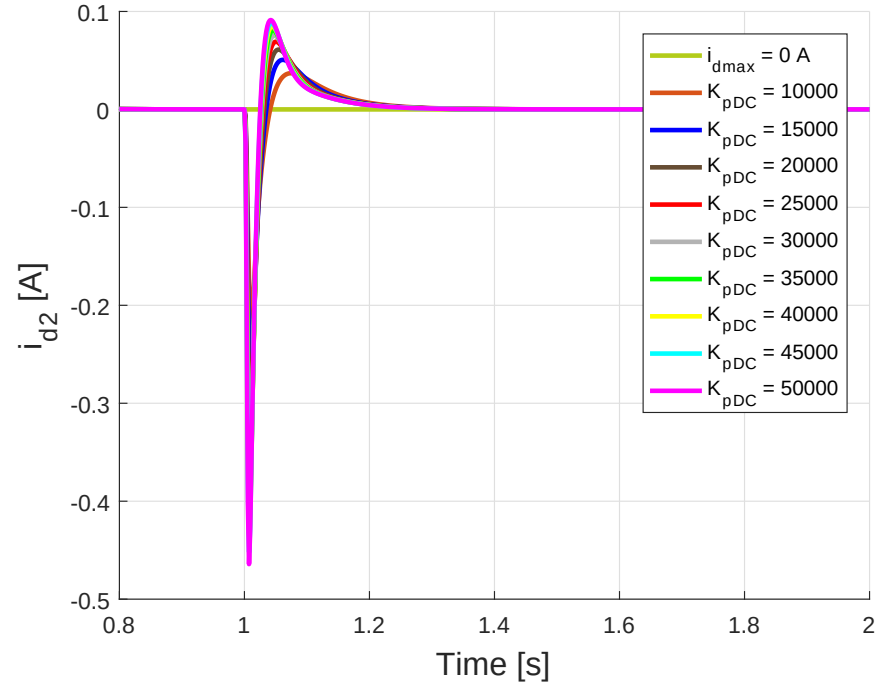

Figure A.82: Current i_{d2} from simulation 3 of Case 1

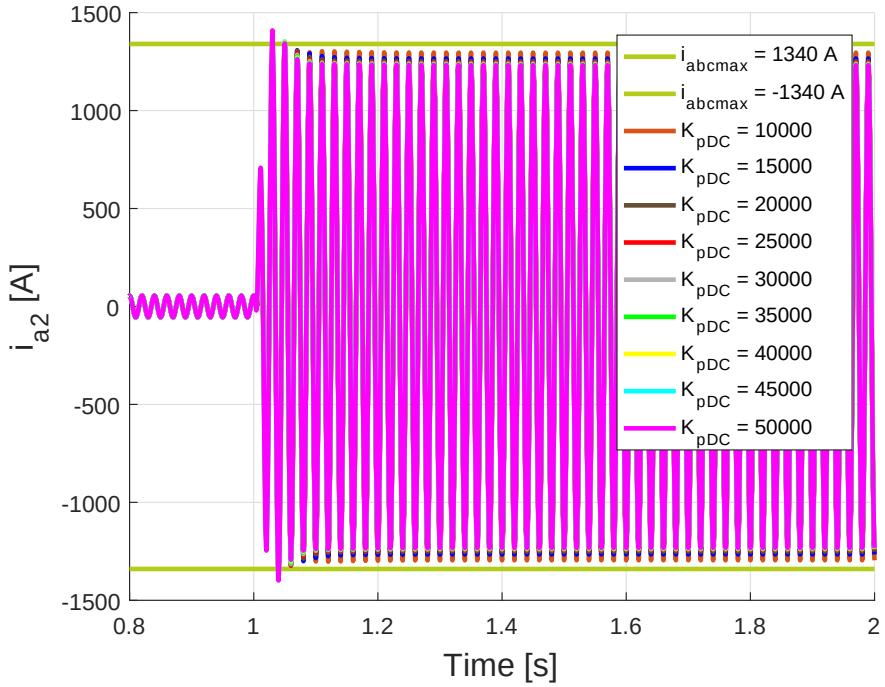

Figure A.83: Current i_{a2} from simulation 3 of Case 1

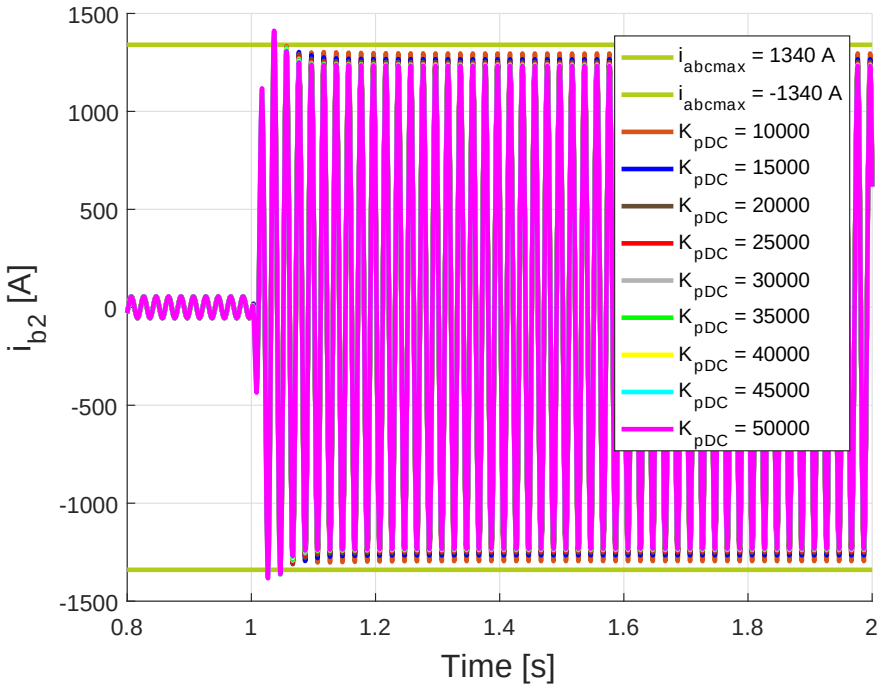

Figure A.84: Current i_{b2} from simulation 3 of Case 1

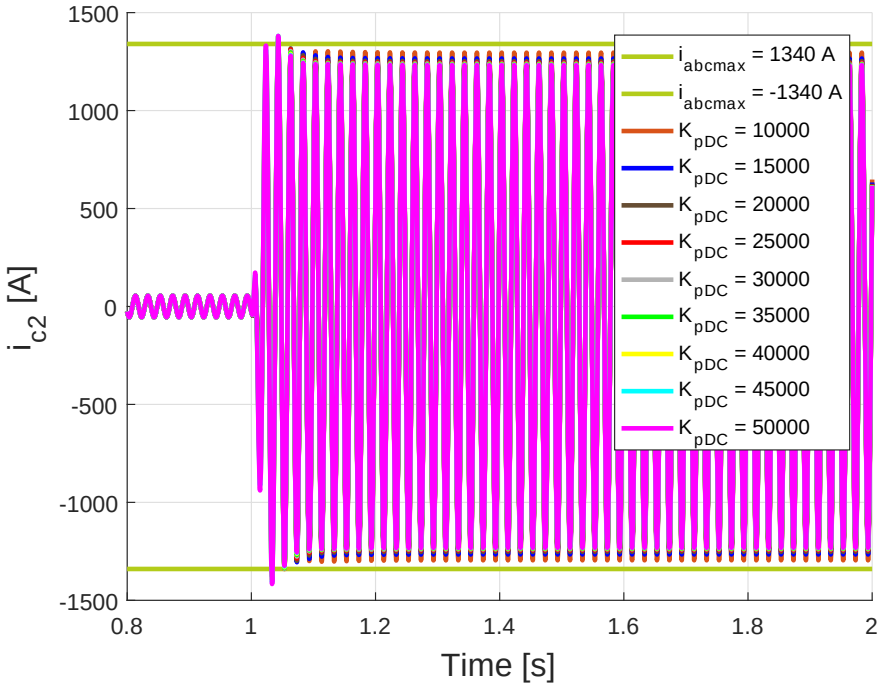

Figure A.85: Current i_{c2} from simulation 3 of Case 1

A.4 Simulation 4

Simulation 4: $K_{pDC} \in [55000, 150000]$ with a step of 9500. In total 11 simulations for each electrical magnitude.

A.4.1 Voltages and currents of the multi-terminal HVDC grid

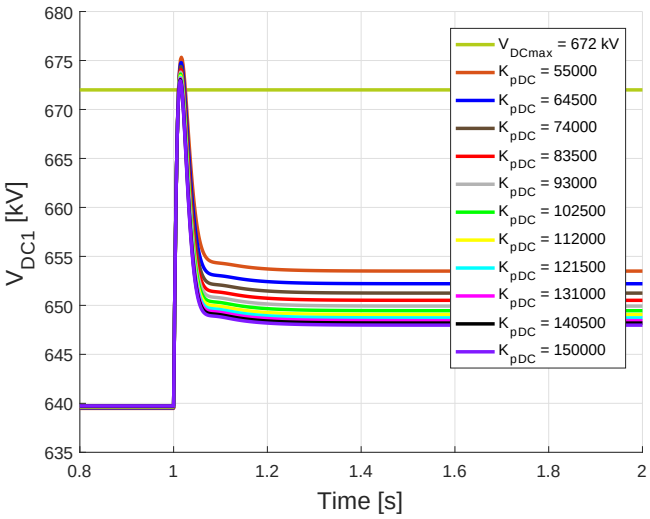

Figure A.86: Voltage V_{DC1} from simulation 4 of Case 1

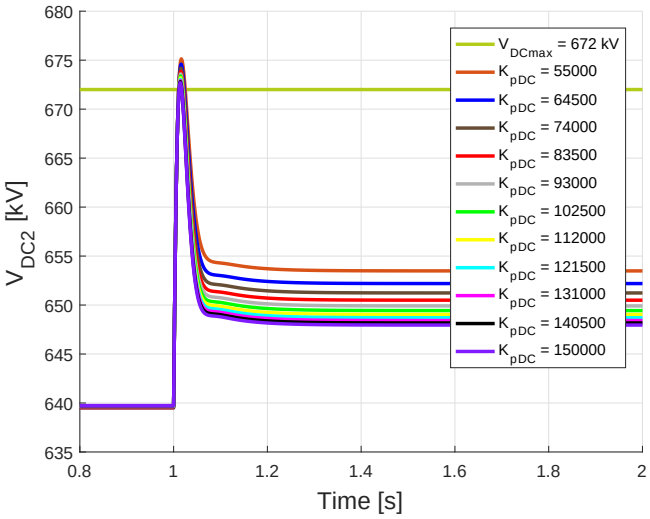

Figure A.87: Voltage V_{DC2} from simulation 4 of Case 1

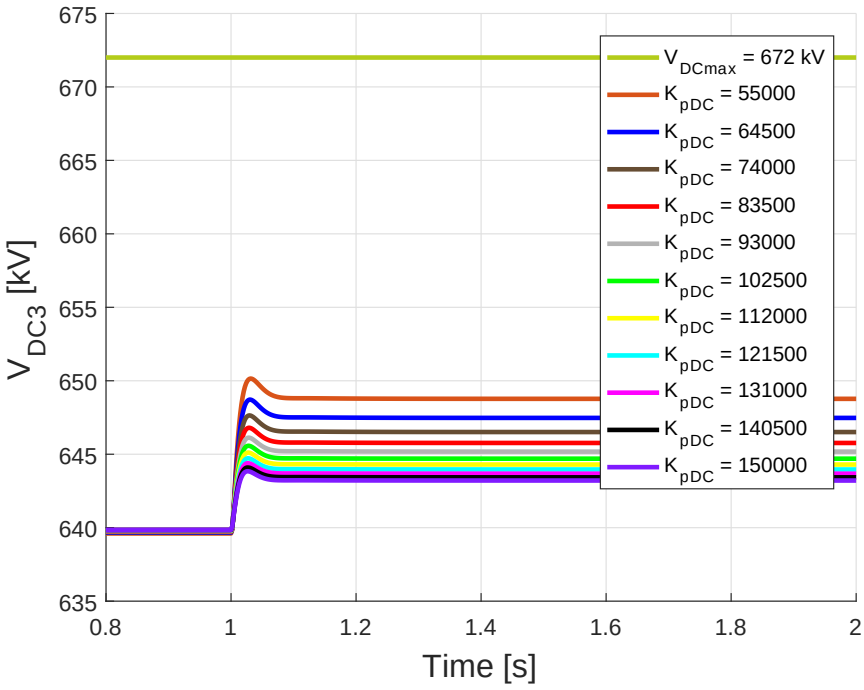

Figure A.88: Voltage V_{DC3} from simulation 4 of Case 1

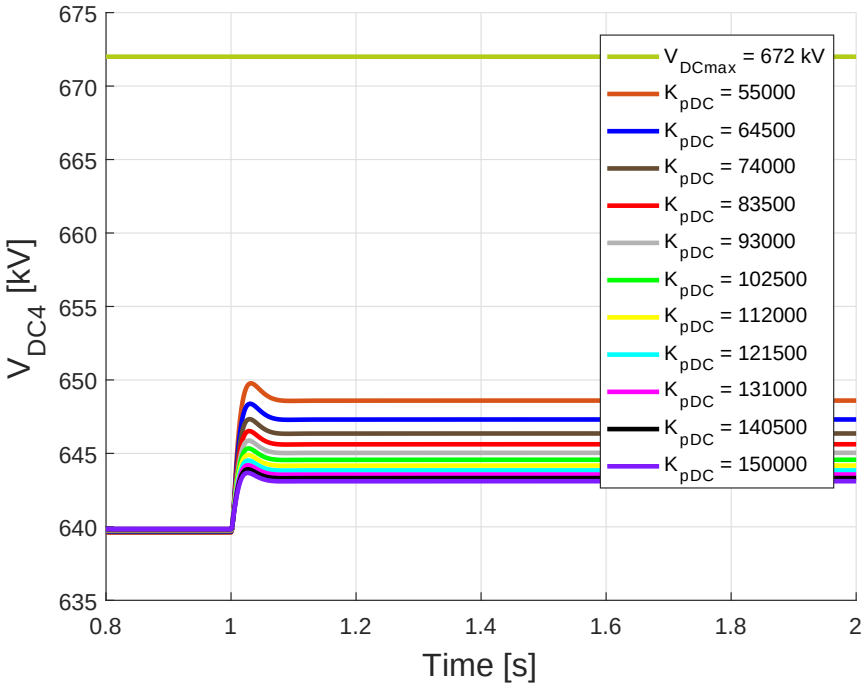

Figure A.89: Voltage V_{DC4} from simulation 4 of Case 1

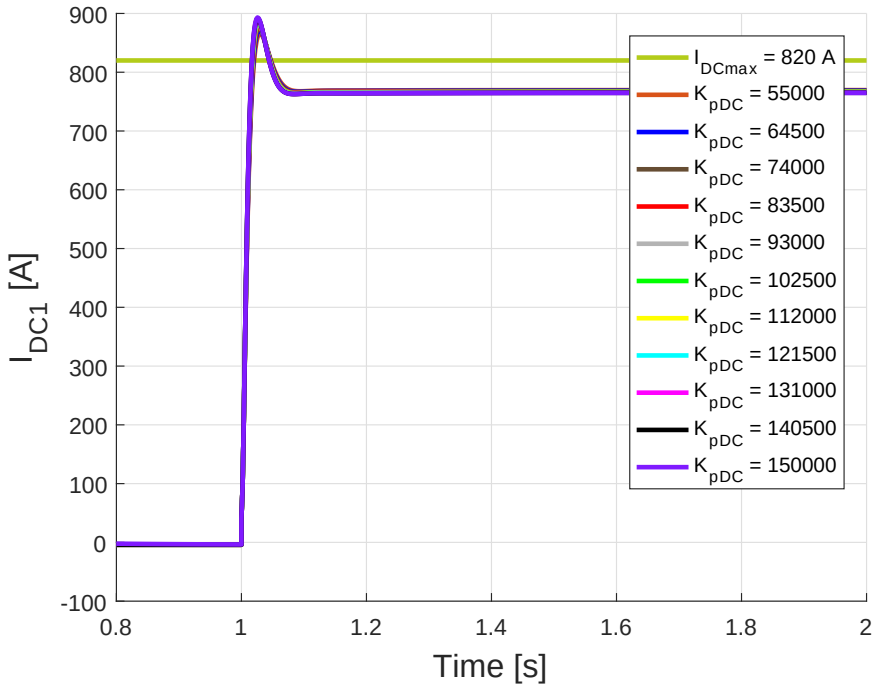

Figure A.90: Current I_{DC1} from simulation 4 of Case 1

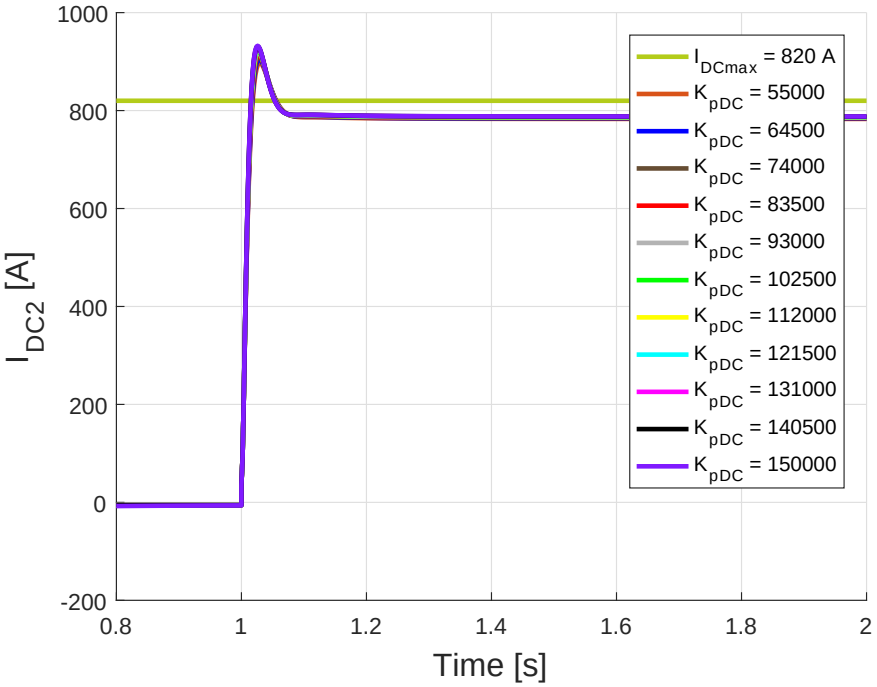

Figure A.91: Current I_{DC2} from simulation 4 of Case 1

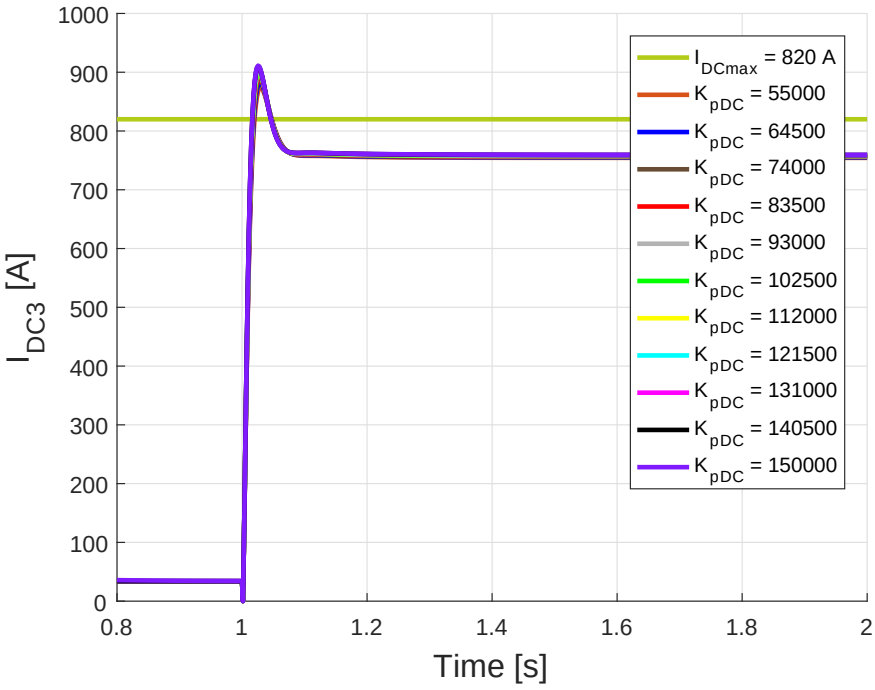

Figure A.92: Current I_{DC3} from simulation 4 of Case 1

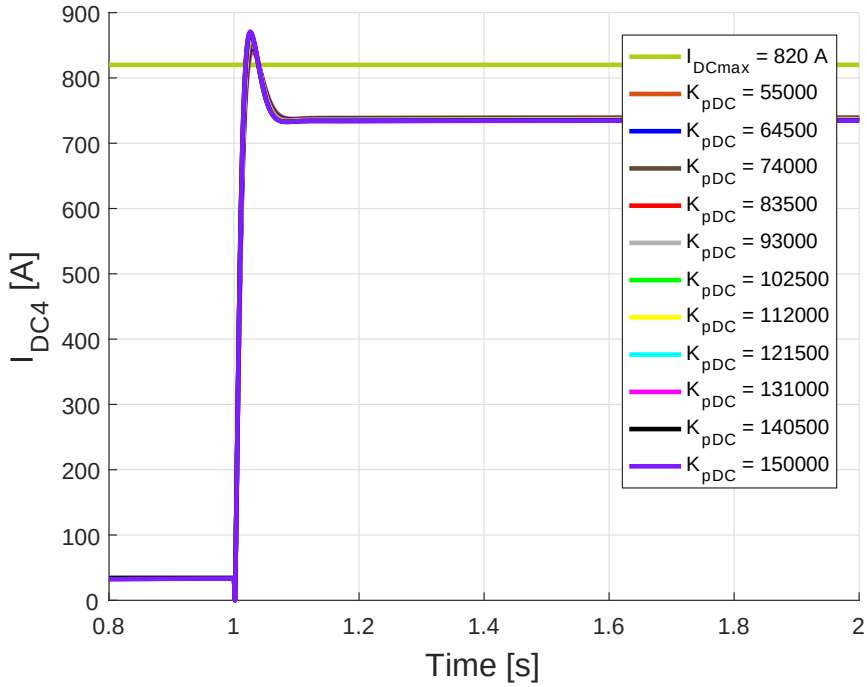

Figure A.93: Current I_{DC4} from simulation 4 of Case 1

A.4.2 Voltages and currents of power converter 1

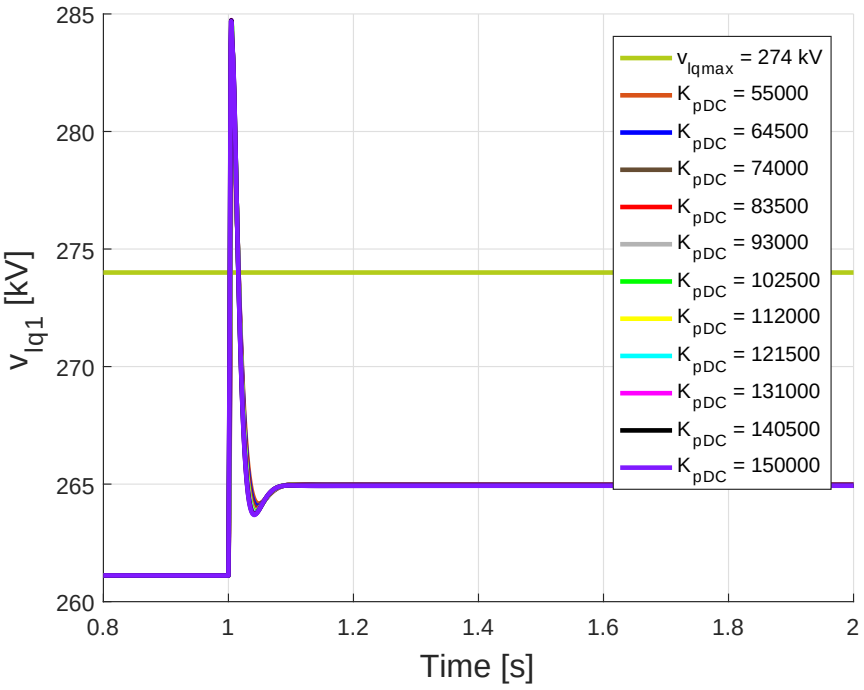

Figure A.94: Voltage v_{lq1} from simulation 4 of Case 1

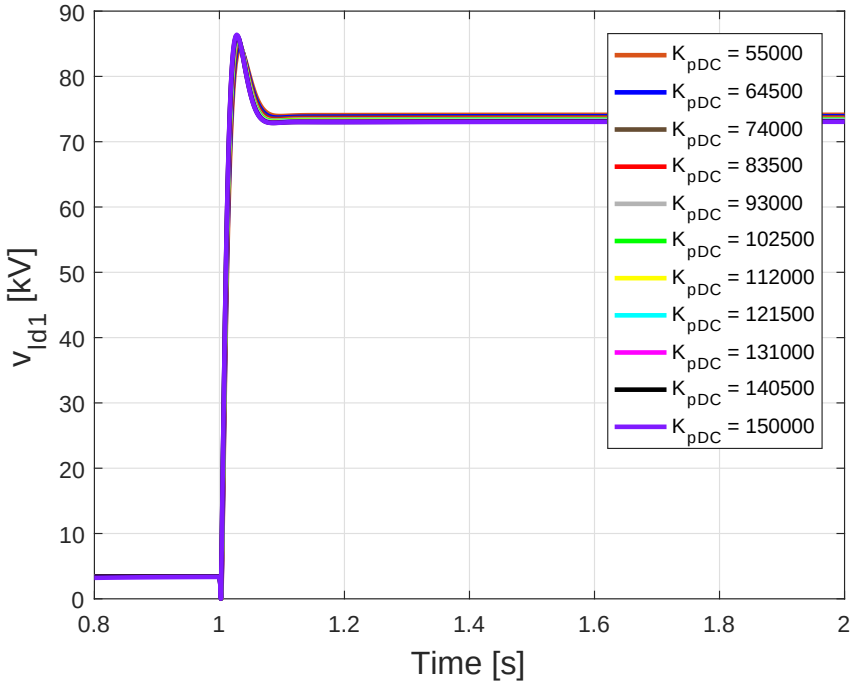

Figure A.95: Voltage v_{ld1} from simulation 4 of Case 1

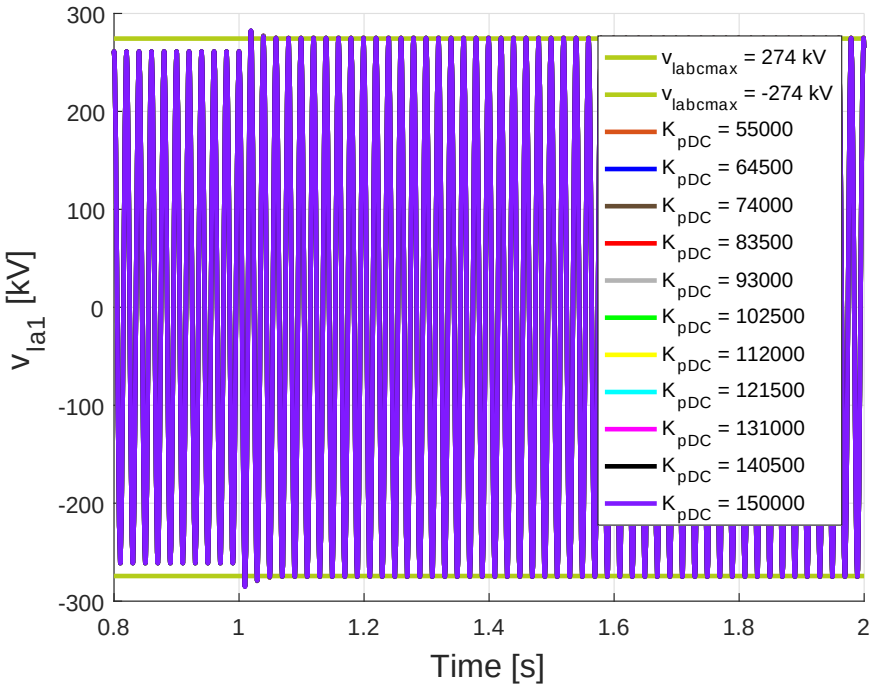

Figure A.96: Voltage v_{la1} from simulation 4 of Case 1

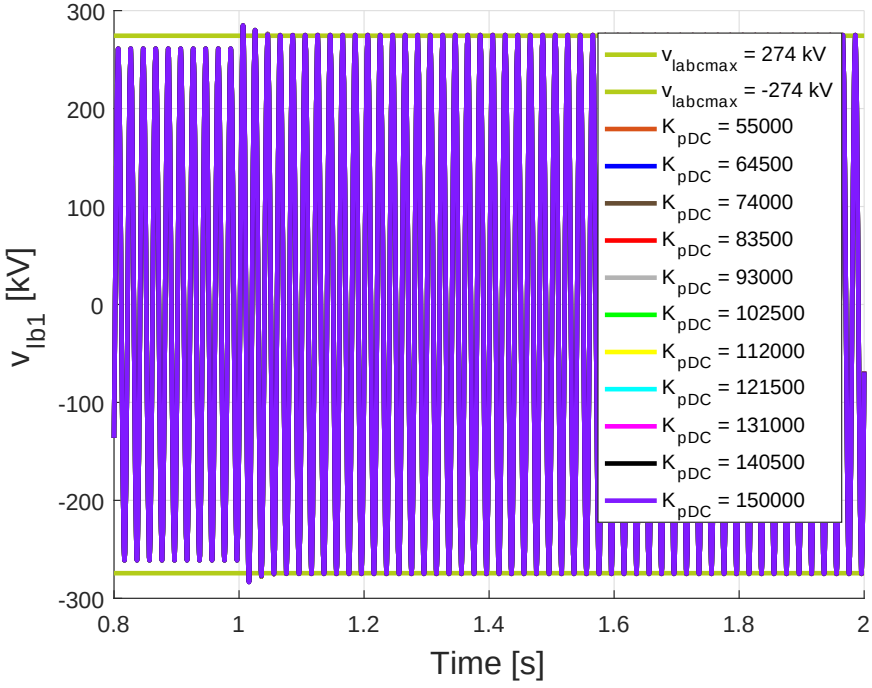

Figure A.97: Voltage v_{lb1} from simulation 4 of Case 1

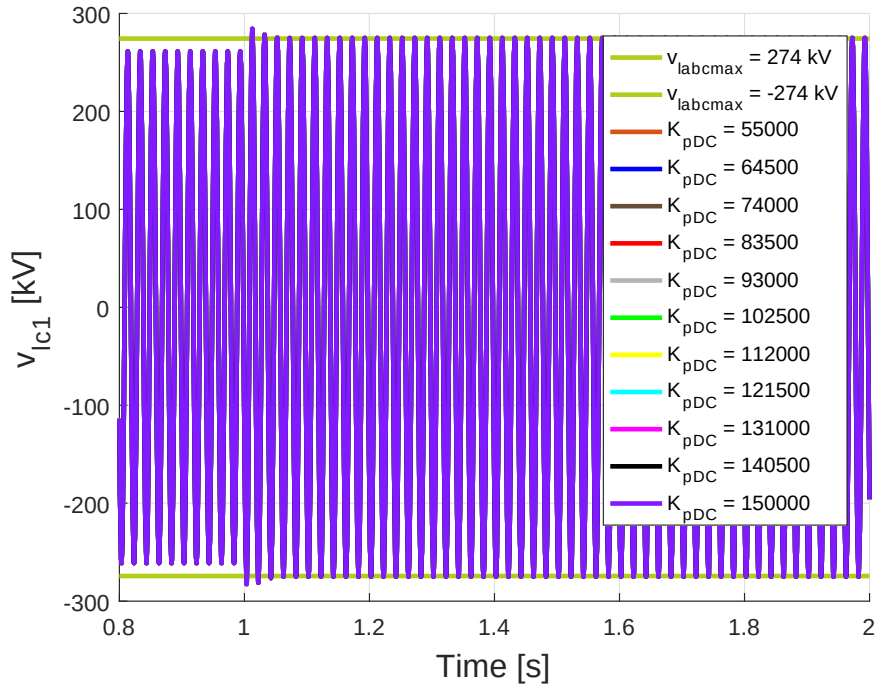

Figure A.98: Voltage v_{lc1} from simulation 4 of Case 1

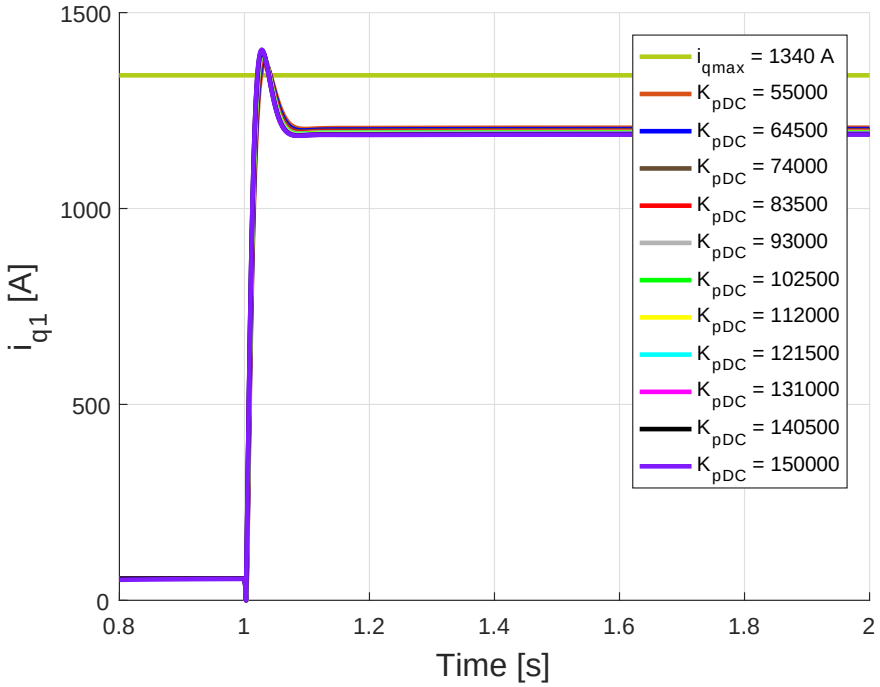

Figure A.99: Current i_{q1} from simulation 4 of Case 1

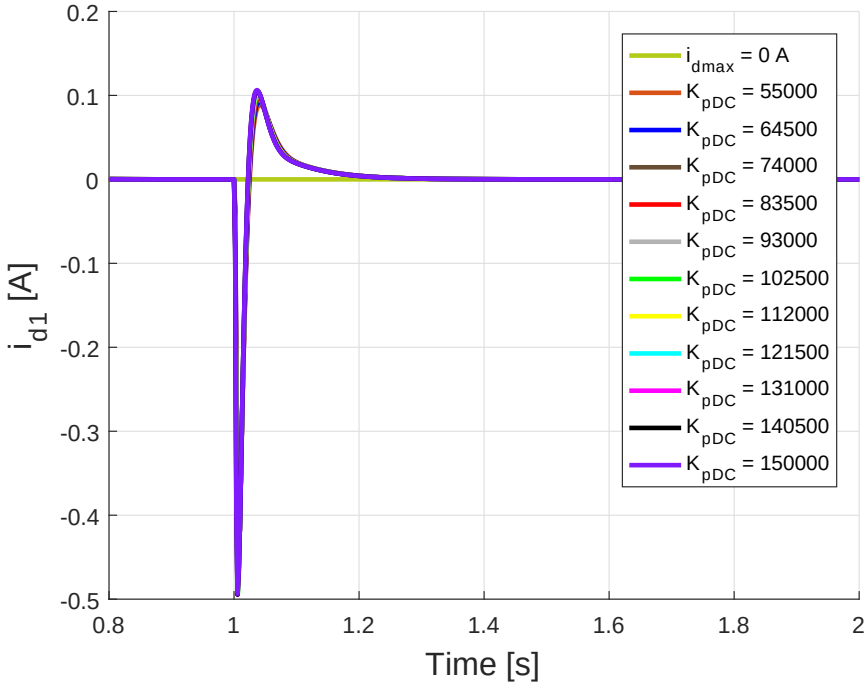

Figure A.100: Current i_{d1} from simulation 4 of Case 1

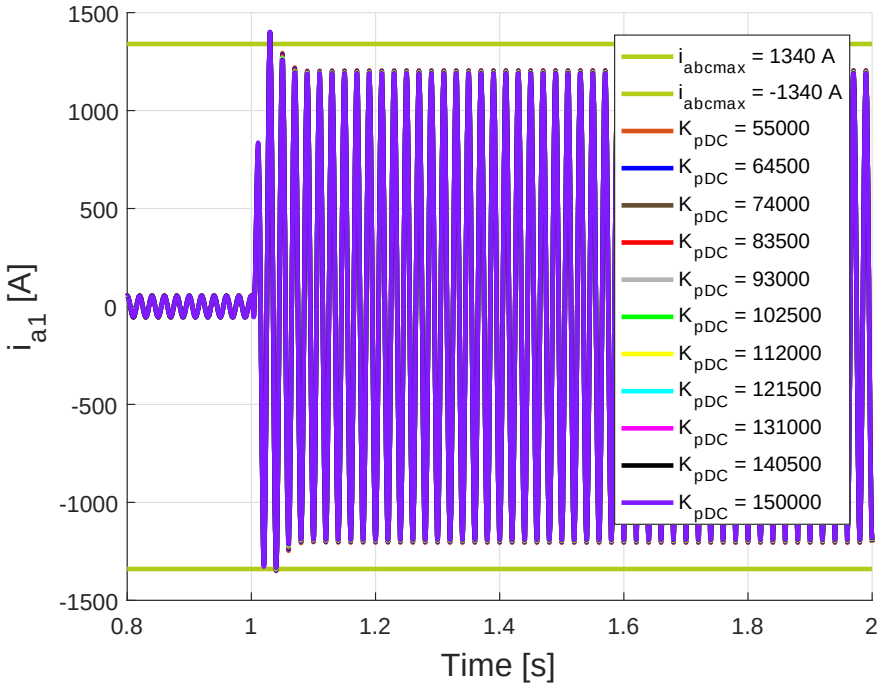

Figure A.101: Current i_{a1} from simulation 4 of Case 1

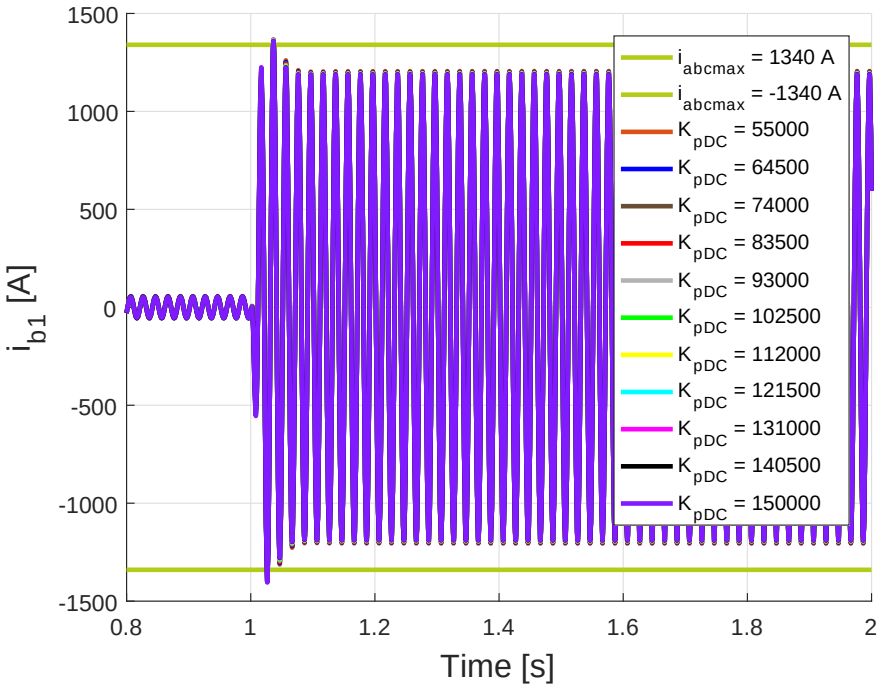

Figure A.102: Current i_{b1} from simulation 4 of Case 1

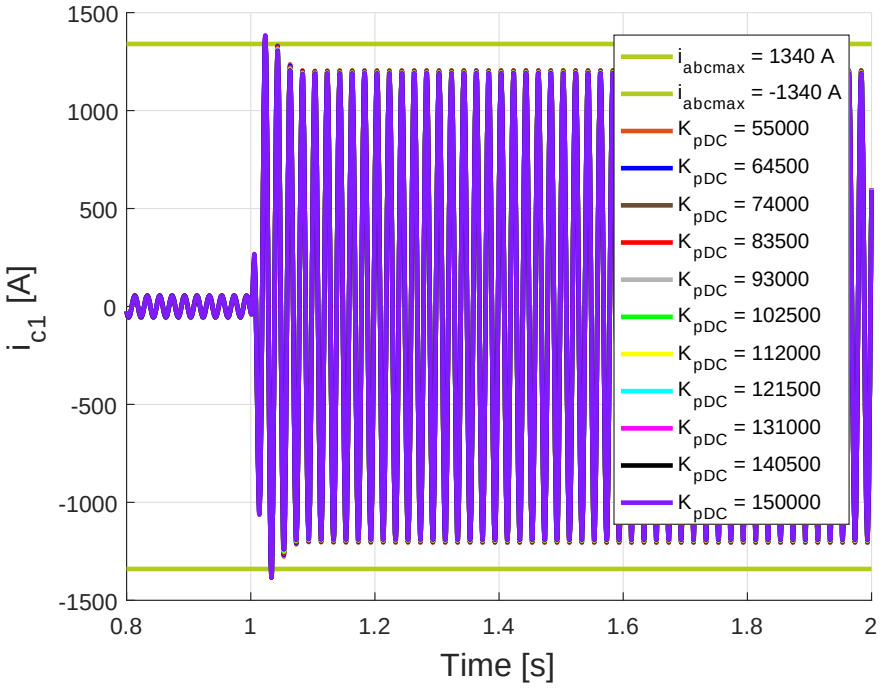

Figure A.103: Current i_{c1} from simulation 4 of Case 1

A.4.3 Voltages and currents of power converter 2

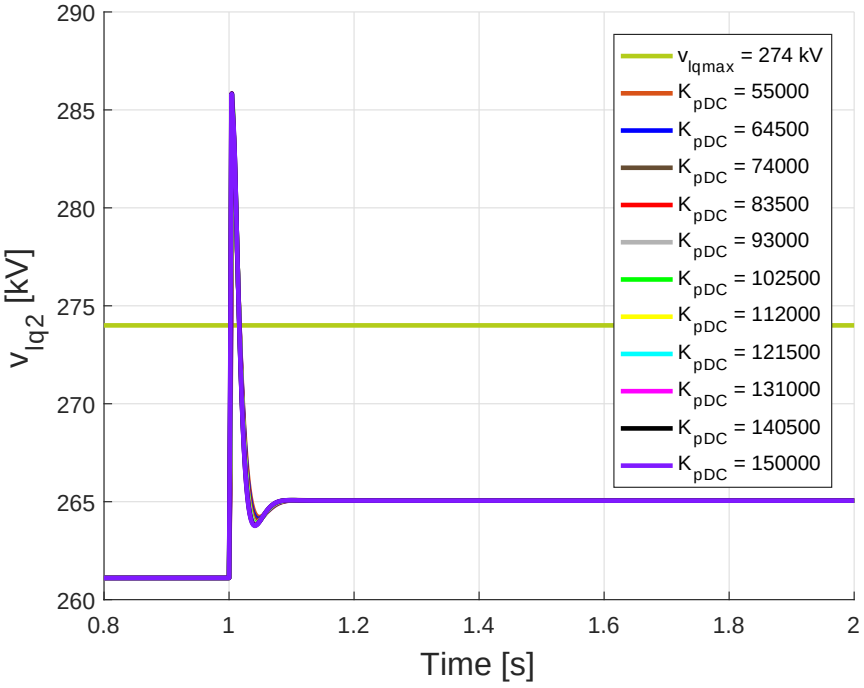

Figure A.104: Voltage v_{lq2} from simulation 4 of Case 1

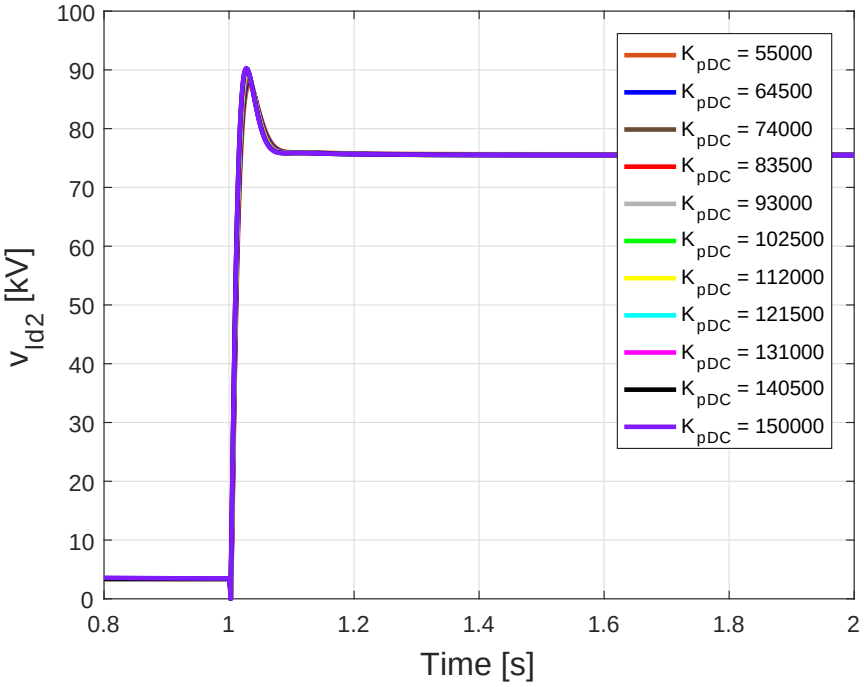

Figure A.105: Voltage v_{ld2} from simulation 4 of Case 1

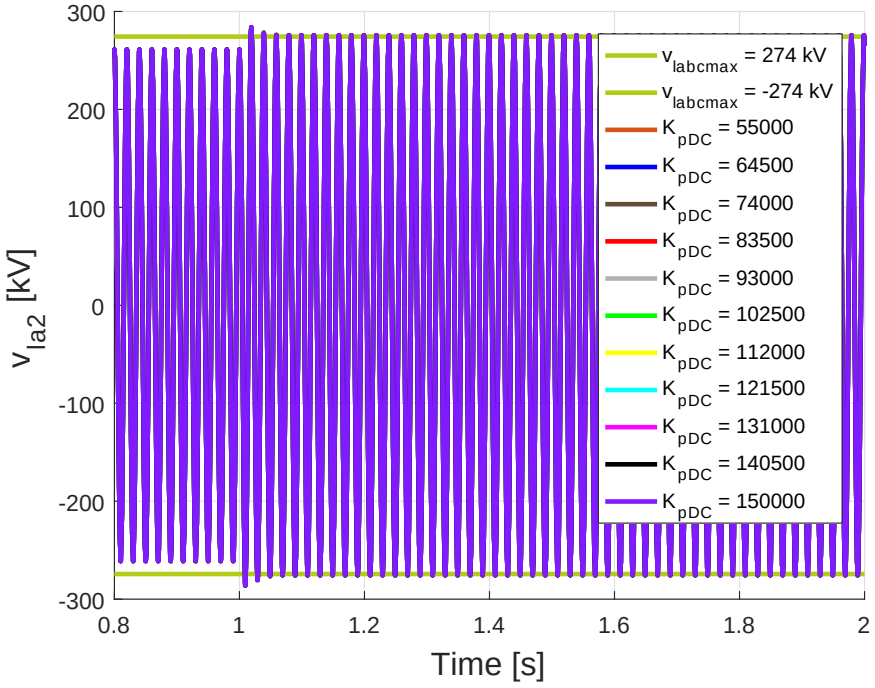

Figure A.106: Voltage v_{la2} from simulation 4 of Case 1

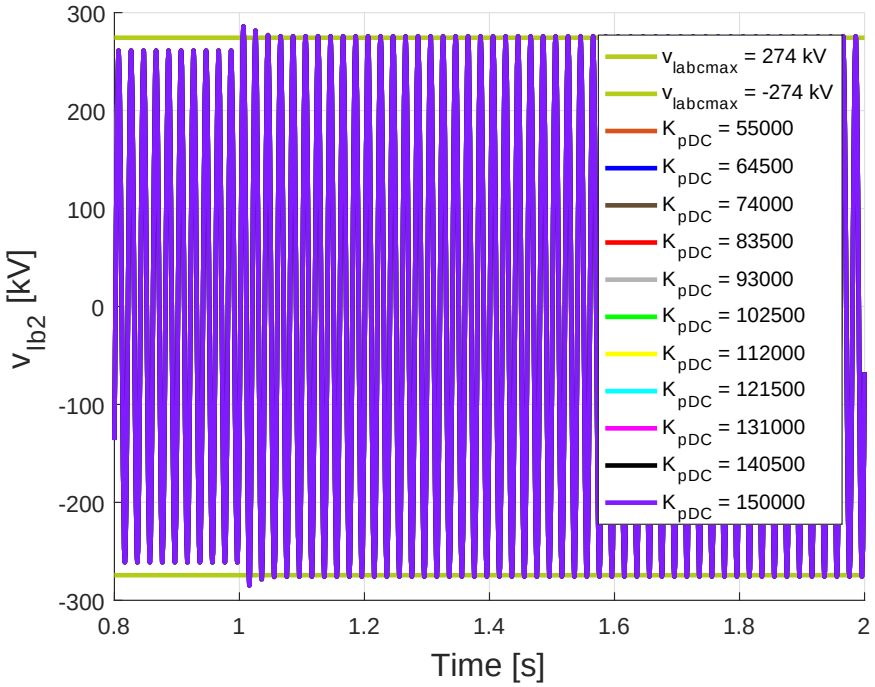

Figure A.107: Voltage v_{lb2} from simulation 4 of Case 1

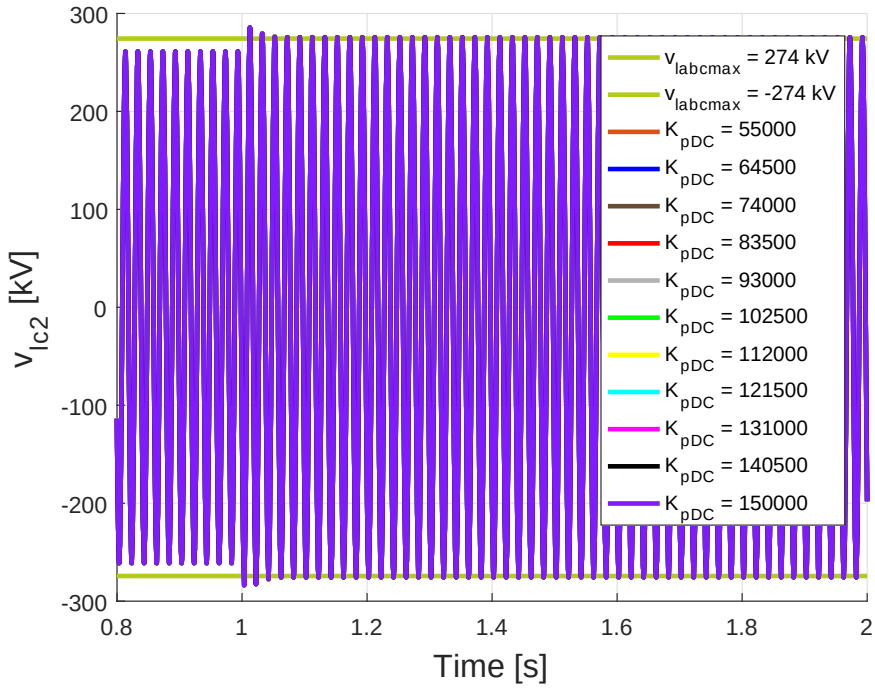

Figure A.108: Voltage v_{lc2} from simulation 4 of Case 1

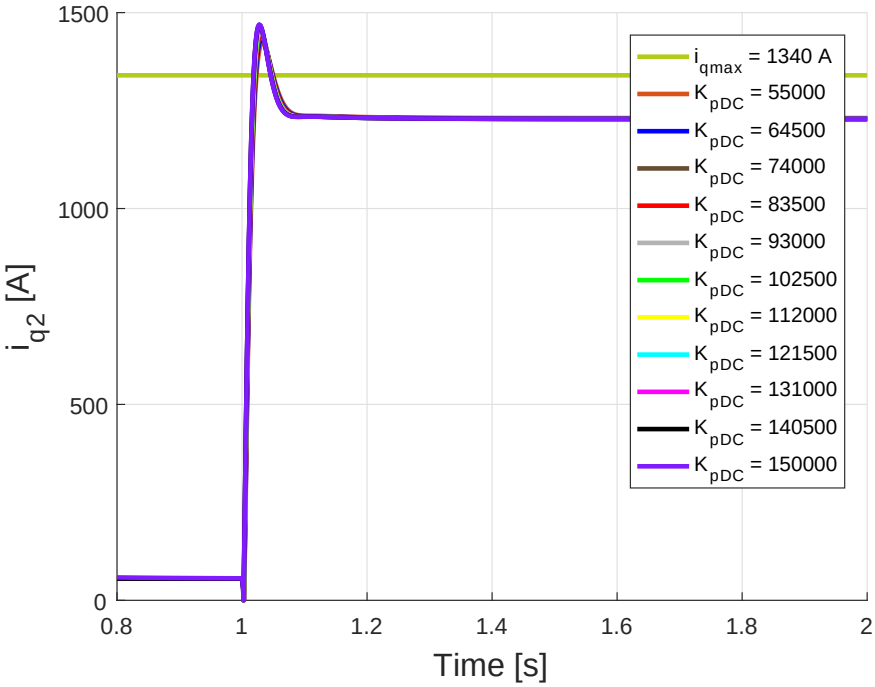

Figure A.109: Current i_{q2} from simulation 4 of Case 1

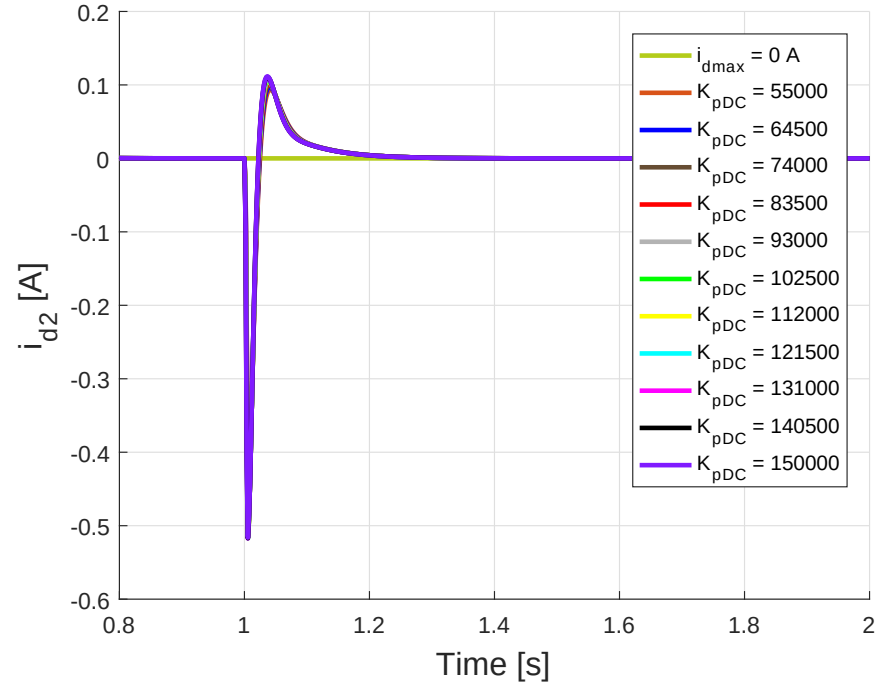

Figure A.110: Current i_{d2} from simulation 4 of Case 1

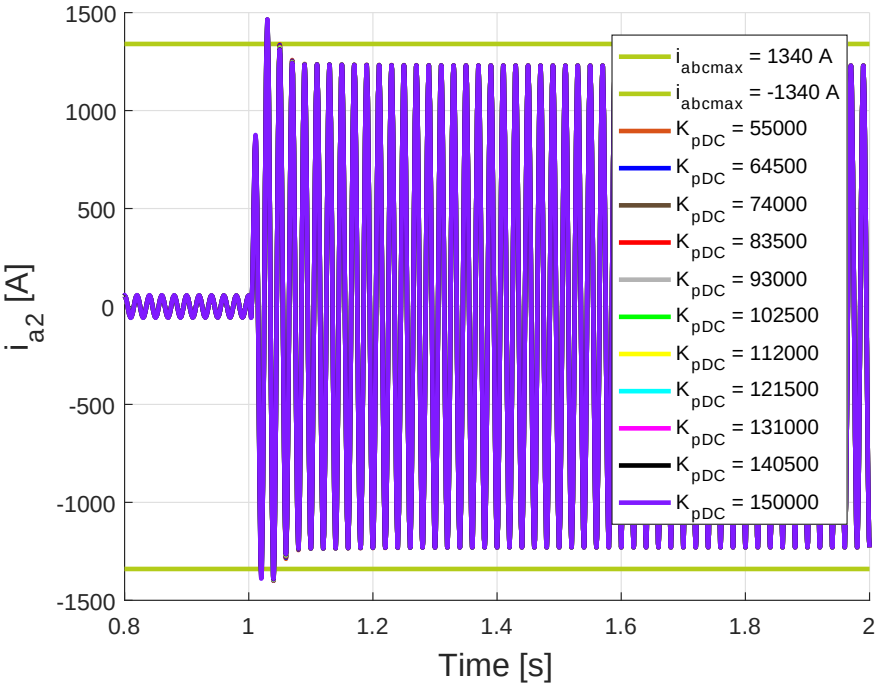

Figure A.111: Current i_{a2} from simulation 4 of Case 1

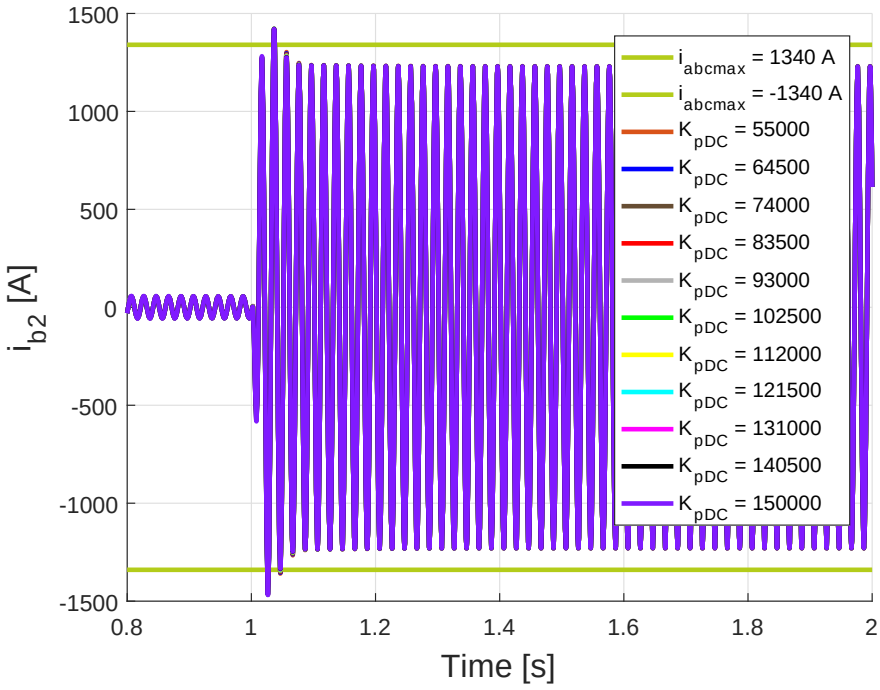

Figure A.112: Current i_{b2} from simulation 4 of Case 1

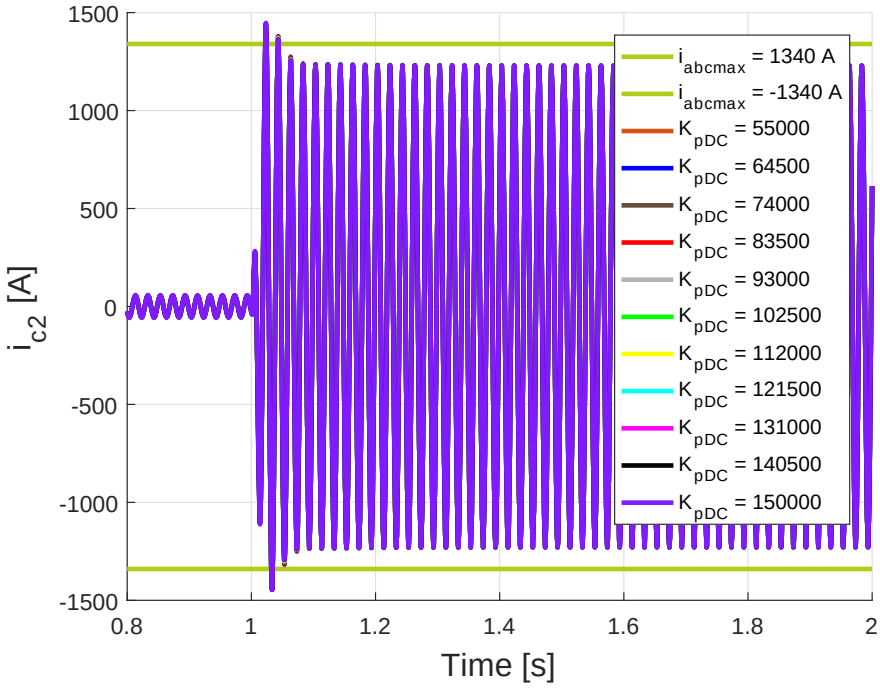

Figure A.113: Current i_{c2} from simulation 4 of Case 1

A.5 Simulation 5

Simulation 5: $K_{pDC} \in [9000, 29000]$ with a step of 2000. In total 11 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

A.5.1 Voltages and currents of the multi-terminal HVDC grid

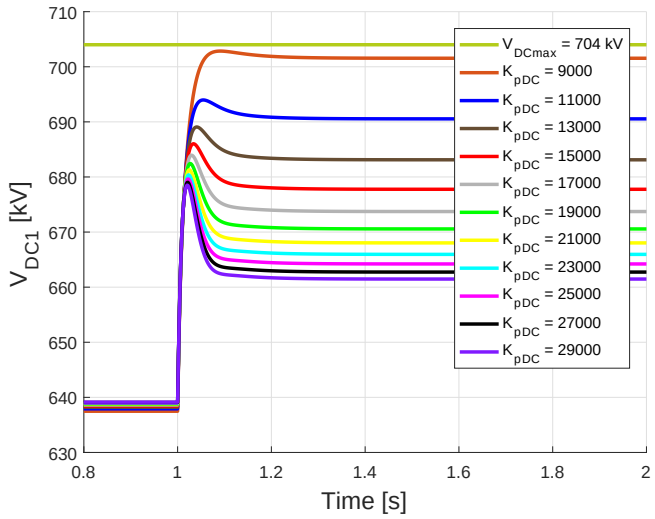

Figure A.114: Voltage V_{DC1} from simulation 5 of Case 1

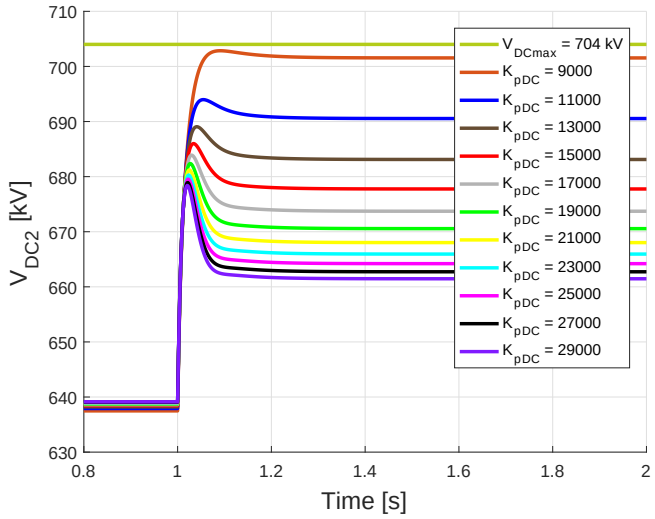

Figure A.115: Voltage V_{DC2} from simulation 5 of Case 1

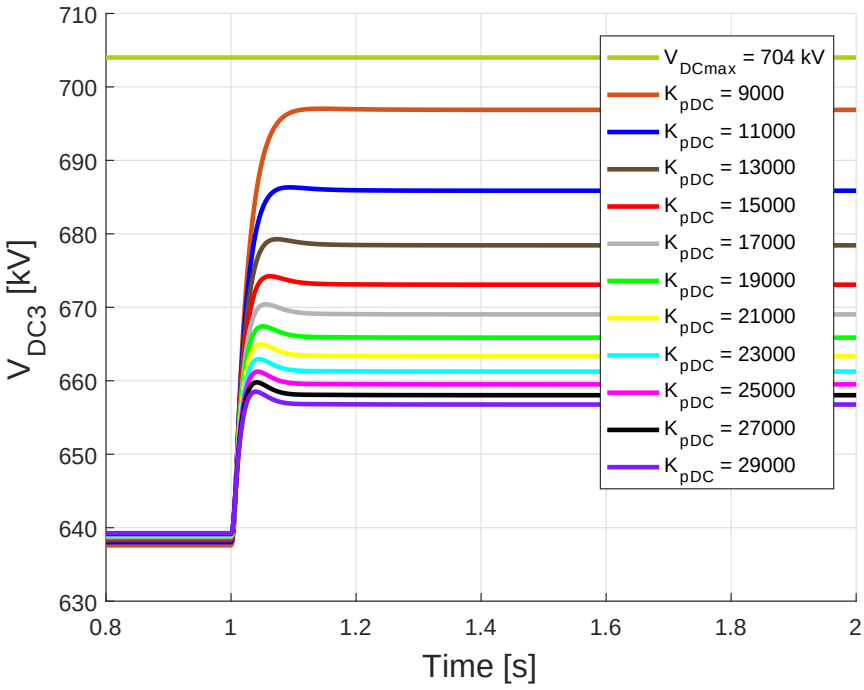

Figure A.116: Voltage V_{DC3} from simulation 5 of Case 1

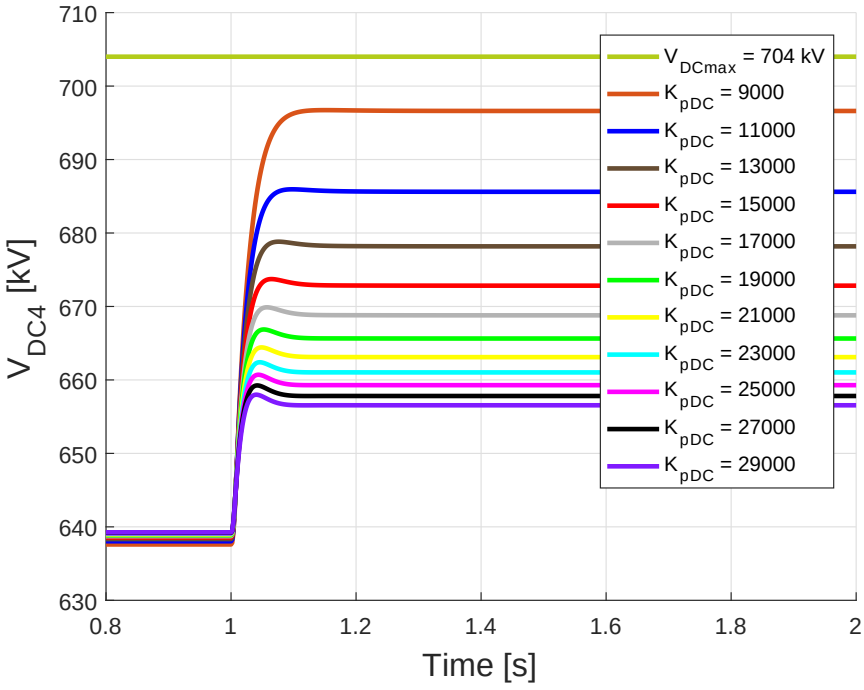

Figure A.117: Voltage V_{DC4} from simulation 5 of Case 1

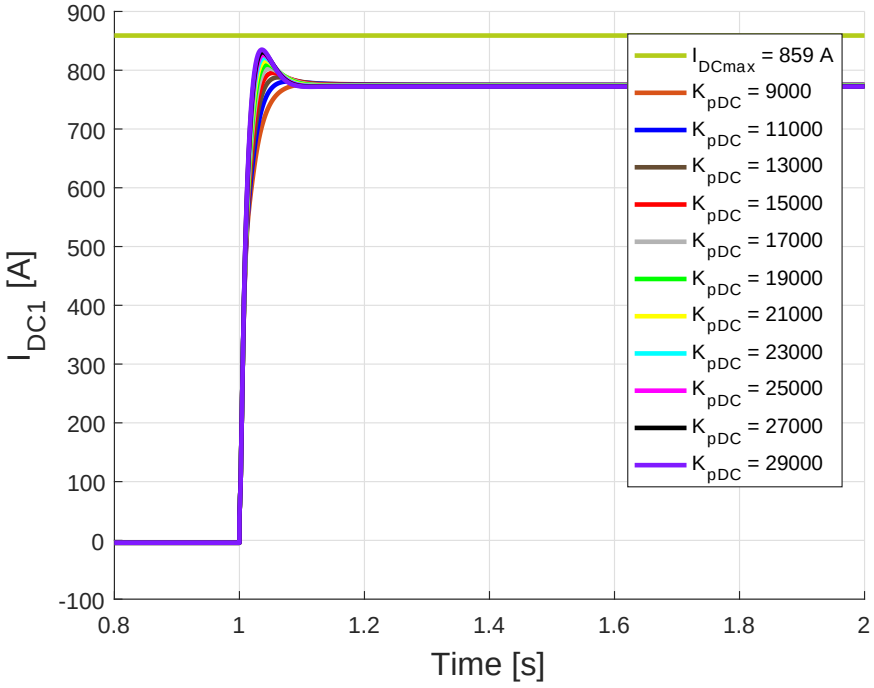

Figure A.118: Current I_{DC1} from simulation 5 of Case 1

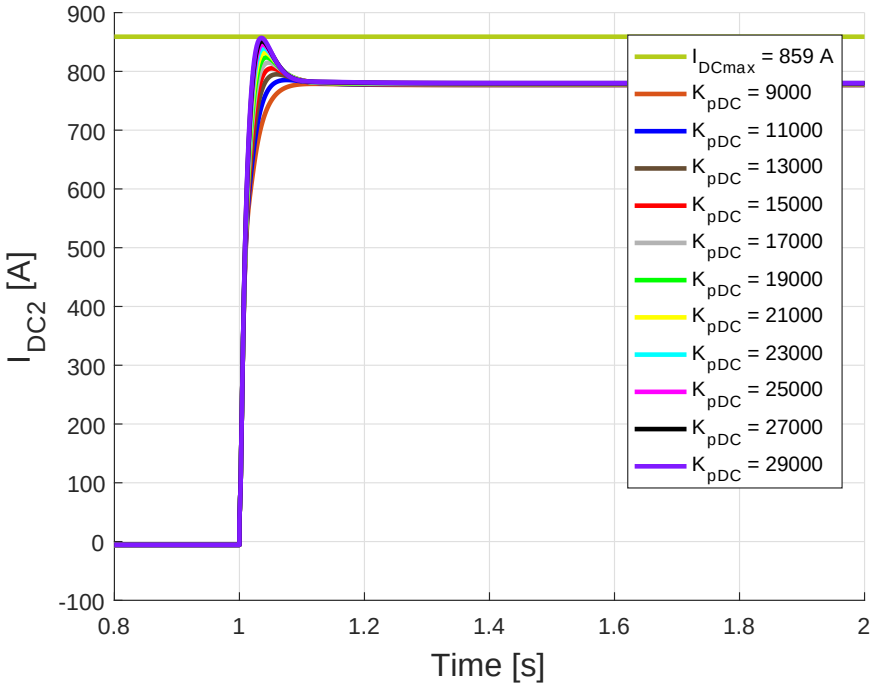

Figure A.119: Current I_{DC2} from simulation 5 of Case 1

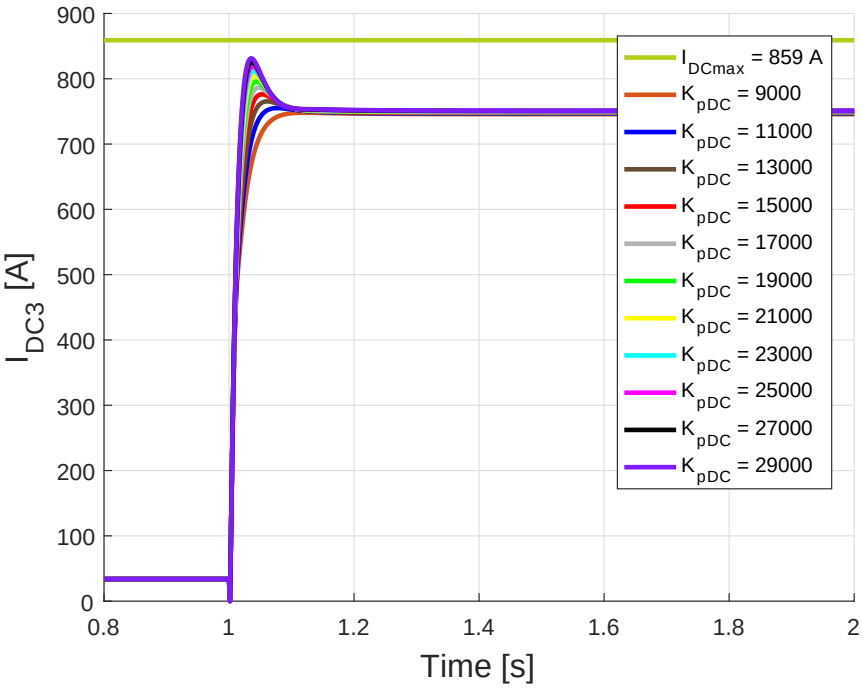

Figure A.120: Current I_{DC3} from simulation 5 of Case 1

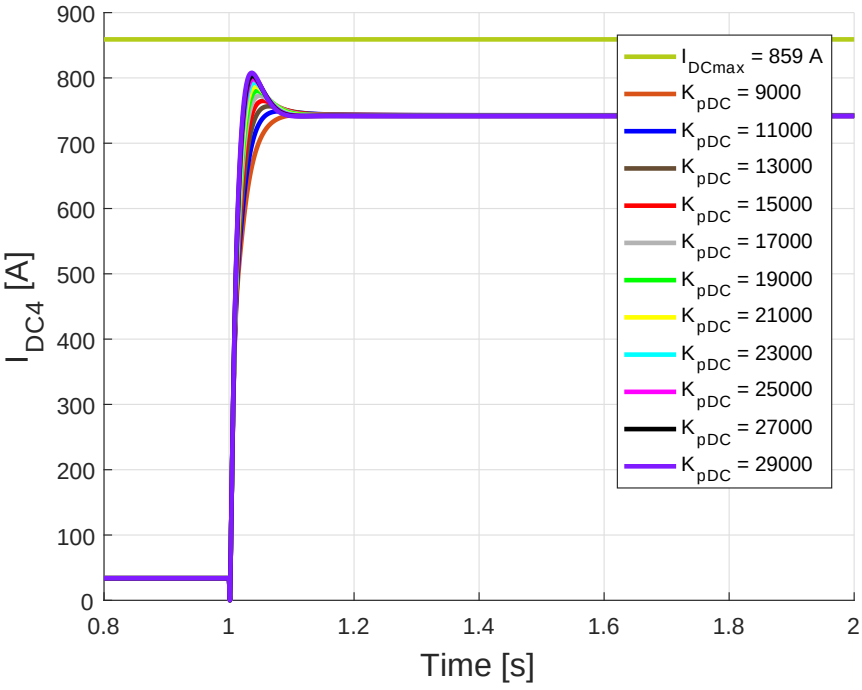

Figure A.121: Current I_{DC4} from simulation 5 of Case 1

A.5.2 Voltages and currents of power converter 1

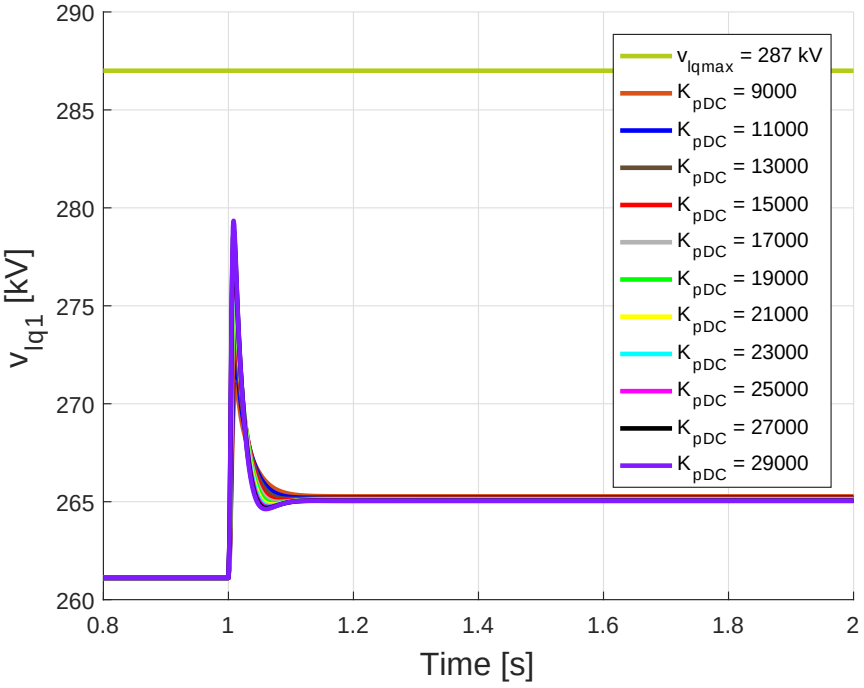

Figure A.122: Voltage v_{lq1} from simulation 5 of Case 1

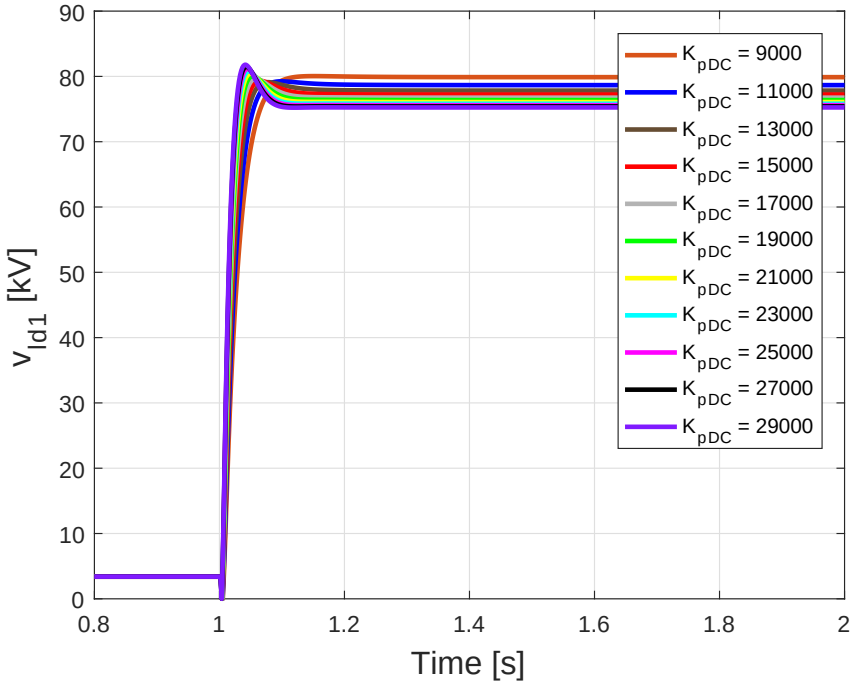

Figure A.123: Voltage v_{ld1} from simulation 5 of Case 1

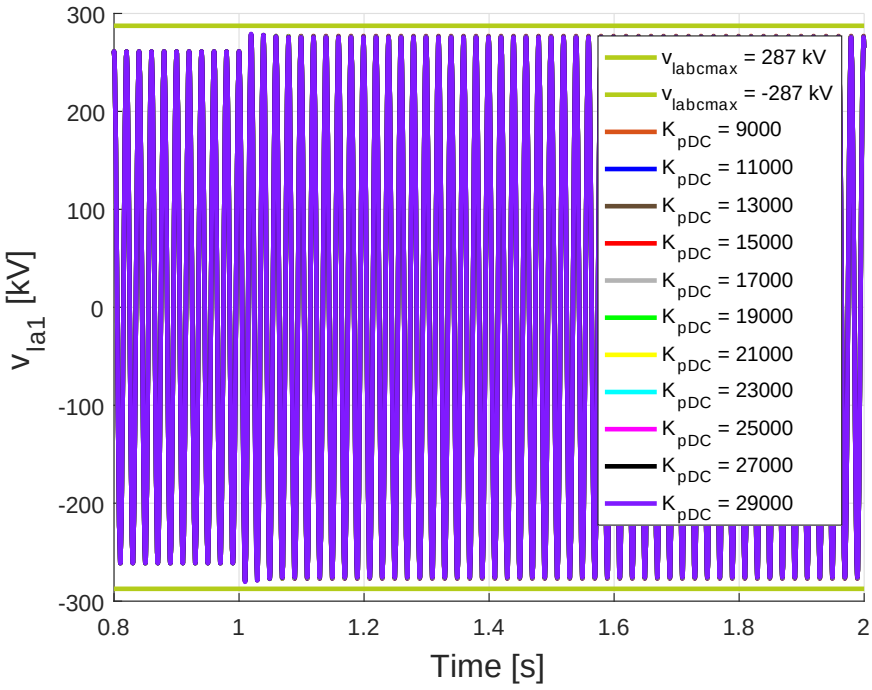

Figure A.124: Voltage v_{la1} from simulation 5 of Case 1

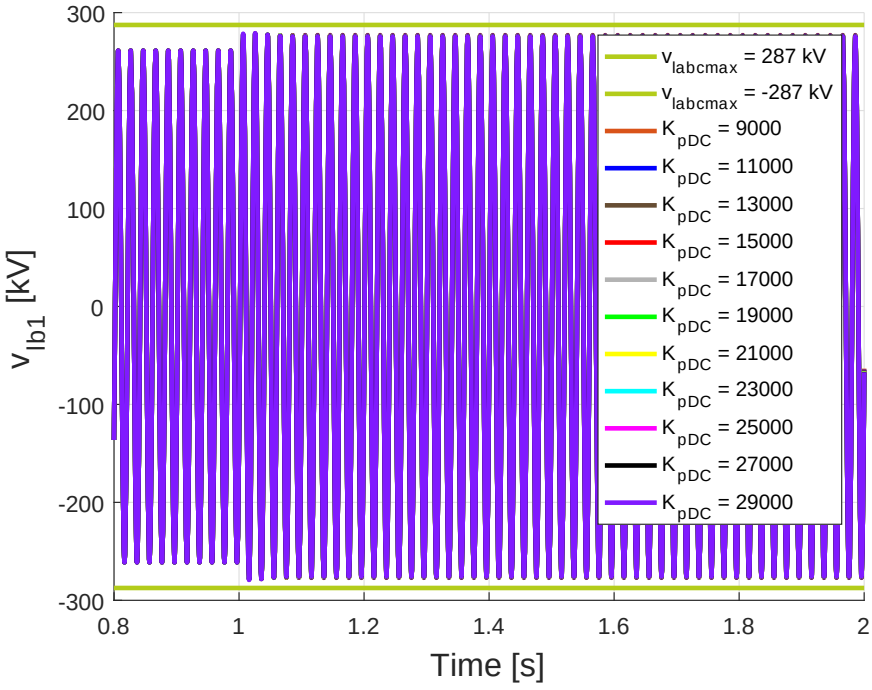

Figure A.125: Voltage v_{lb1} from simulation 5 of Case 1

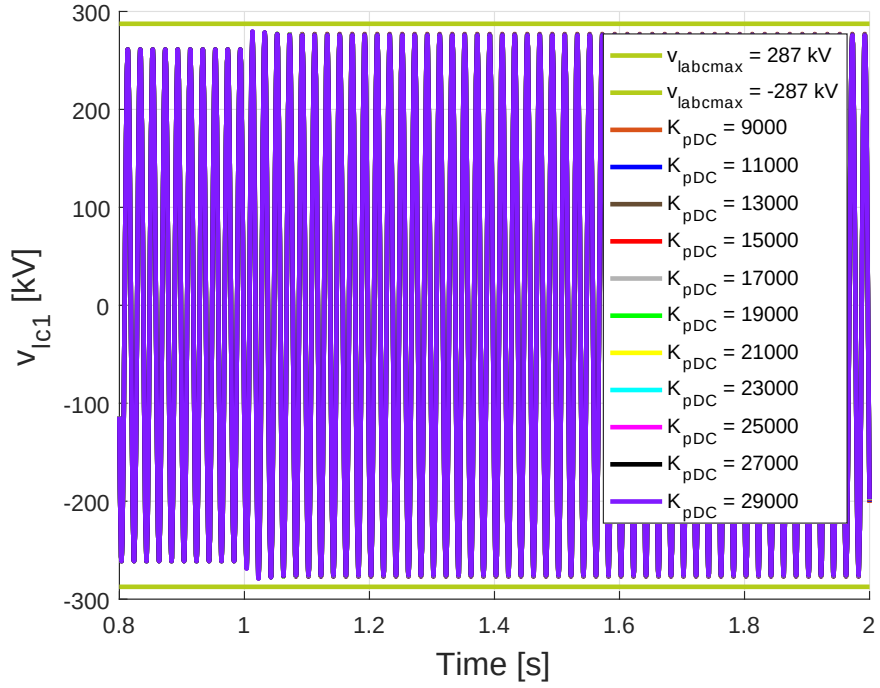

Figure A.126: Voltage v_{lc1} from simulation 5 of Case 1

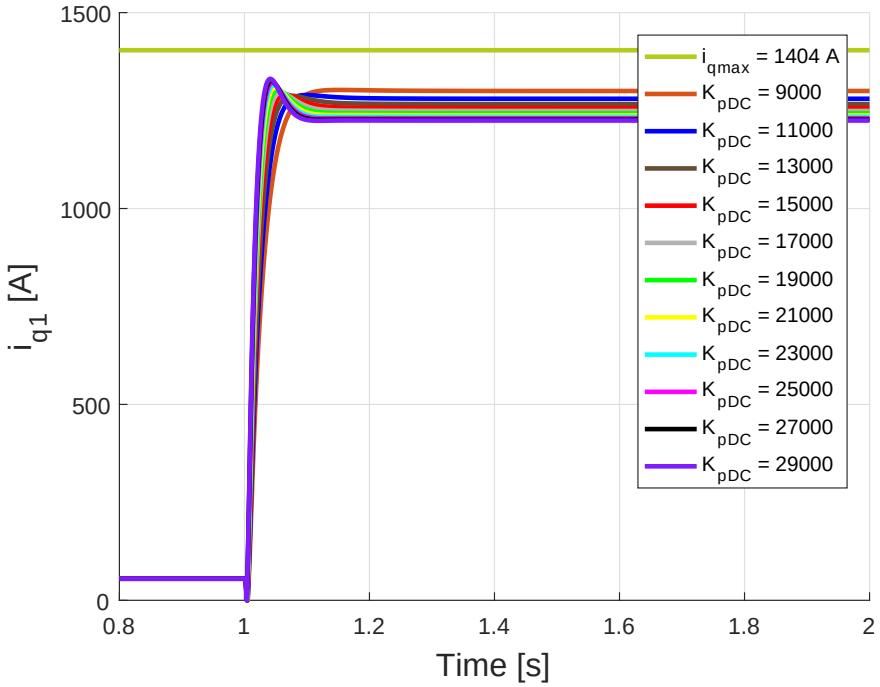

Figure A.127: Current i_{q1} from simulation 5 of Case 1

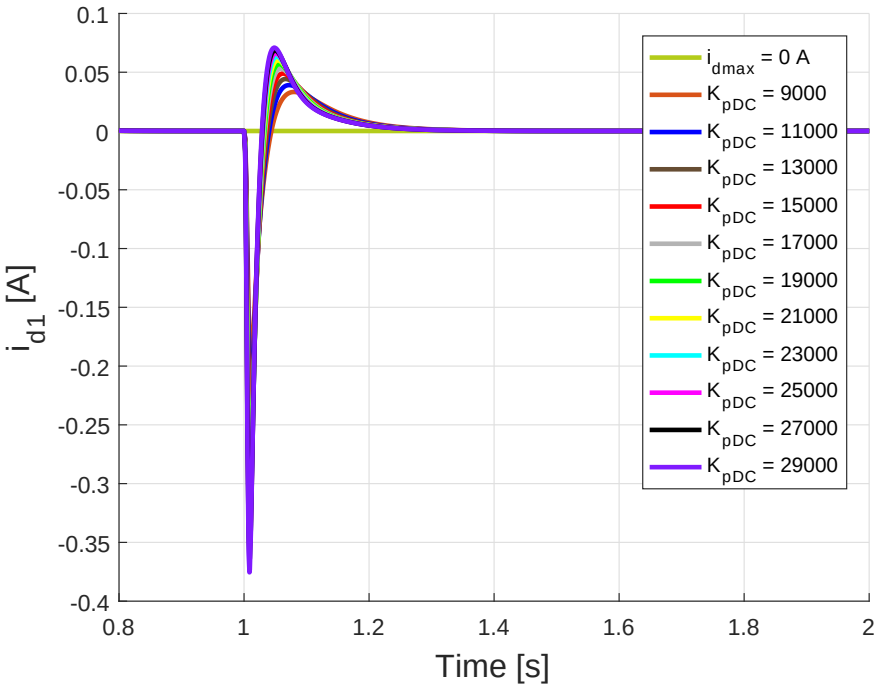

Figure A.128: Current i_{d1} from simulation 5 of Case 1

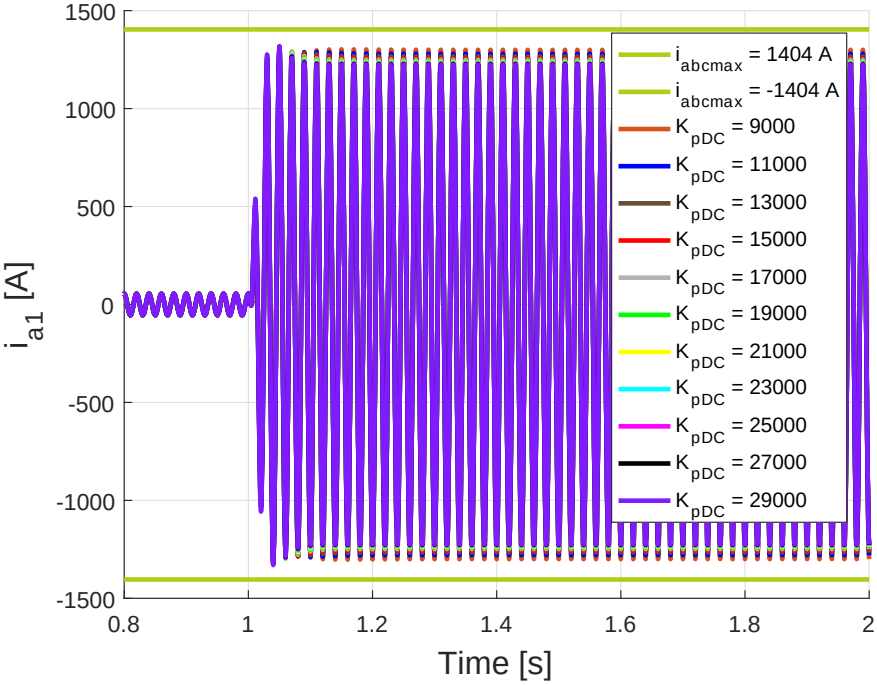

Figure A.129: Current i_{a1} from simulation 5 of Case 1

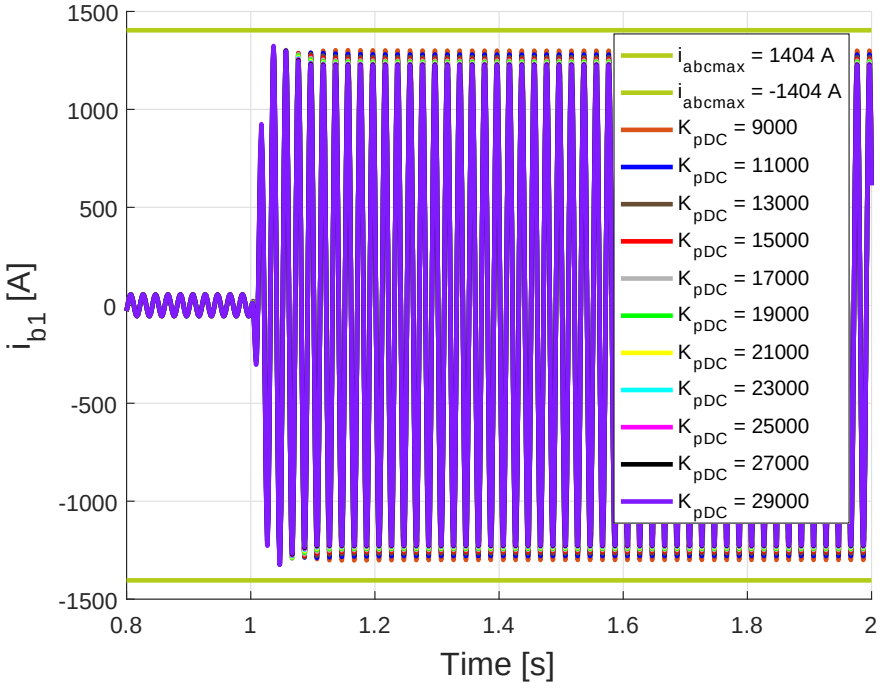

Figure A.130: Current i_{b1} from simulation 5 of Case 1

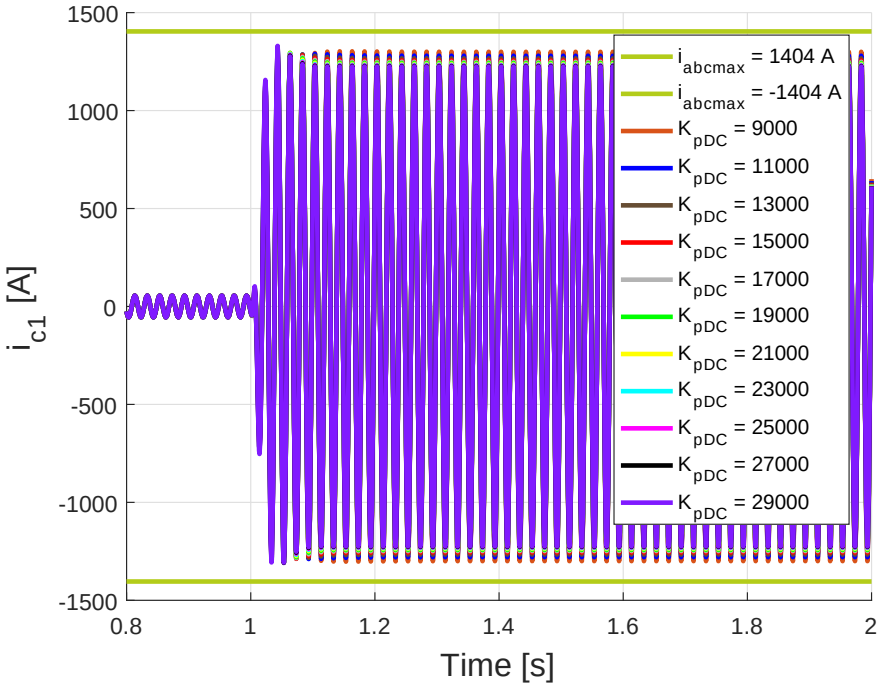

Figure A.131: Current i_{c1} from simulation 5 of Case 1

A.5.3 Voltages and currents of power converter 2

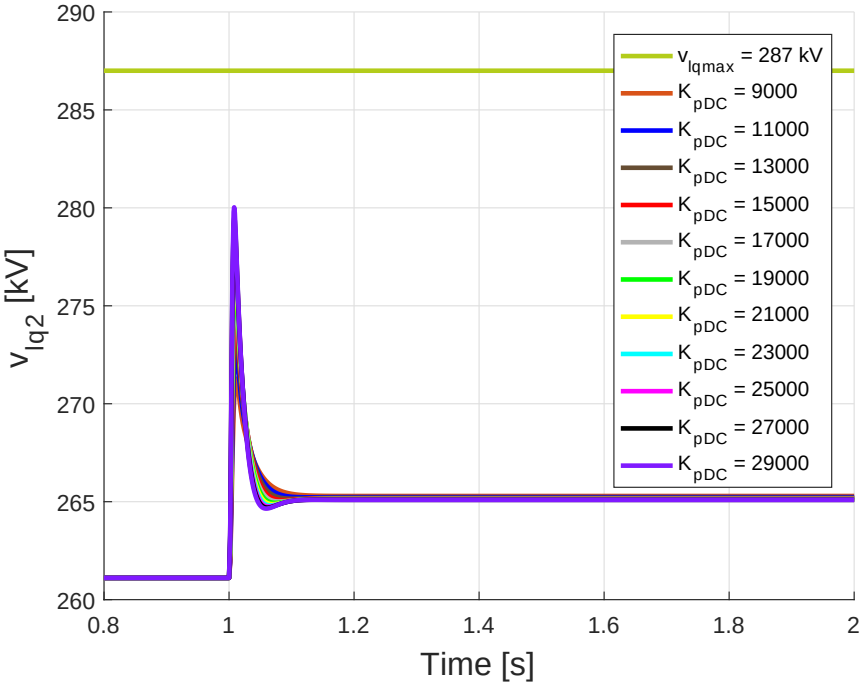

Figure A.132: Voltage v_{lq2} from simulation 5 of Case 1

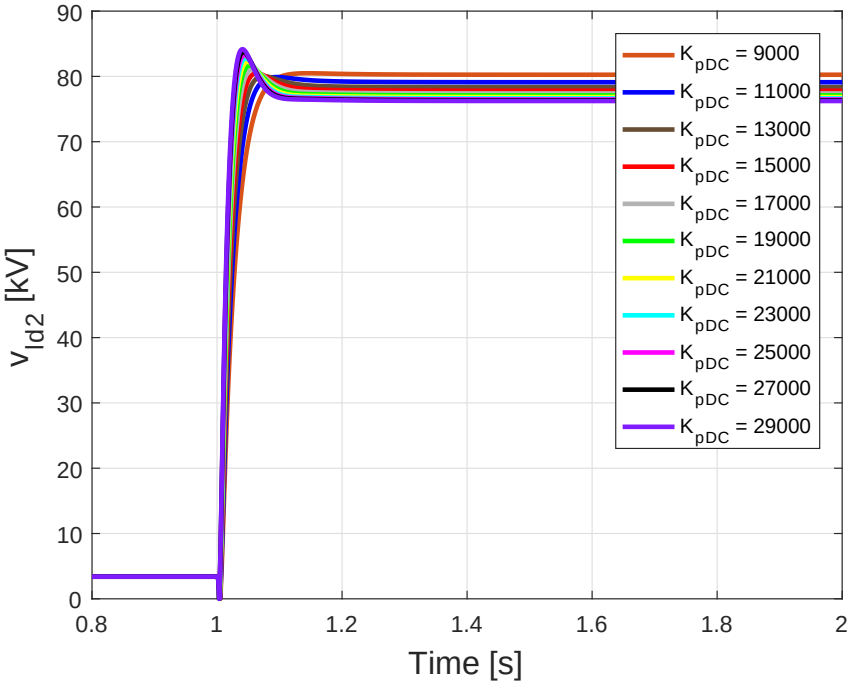

Figure A.133: Voltage v_{ld2} from simulation 5 of Case 1

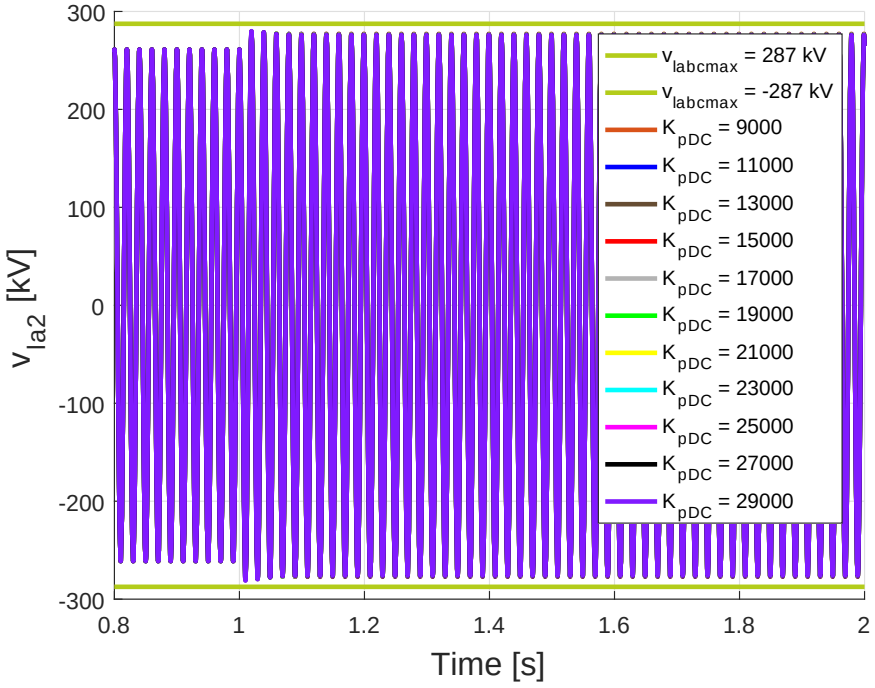

Figure A.134: Voltage v_{la2} from simulation 5 of Case 1

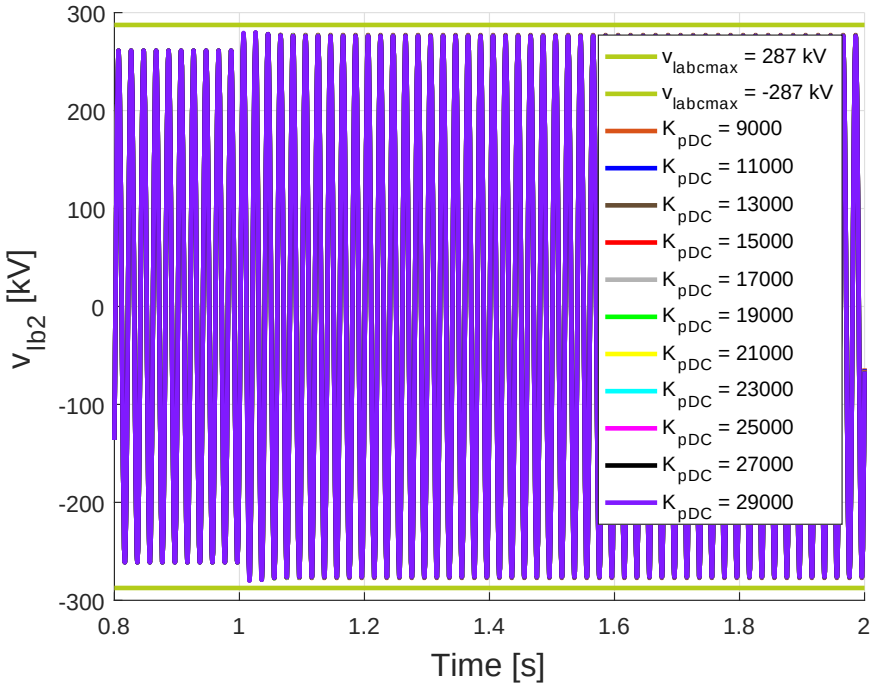

Figure A.135: Voltage v_{lb2} from simulation 5 of Case 1

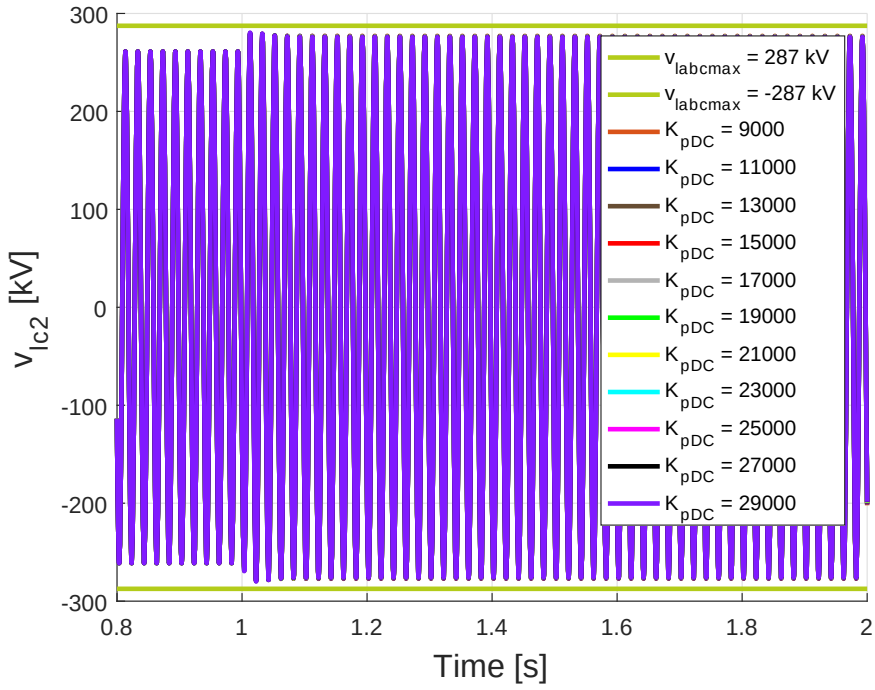

Figure A.136: Voltage v_{lc2} from simulation 5 of Case 1

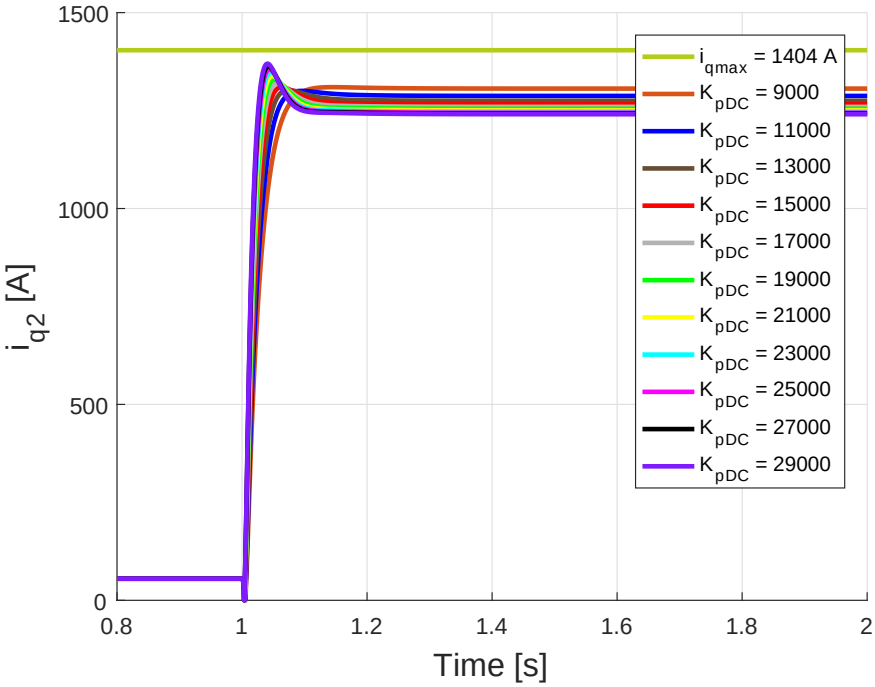

Figure A.137: Current i_{q2} from simulation 5 of Case 1

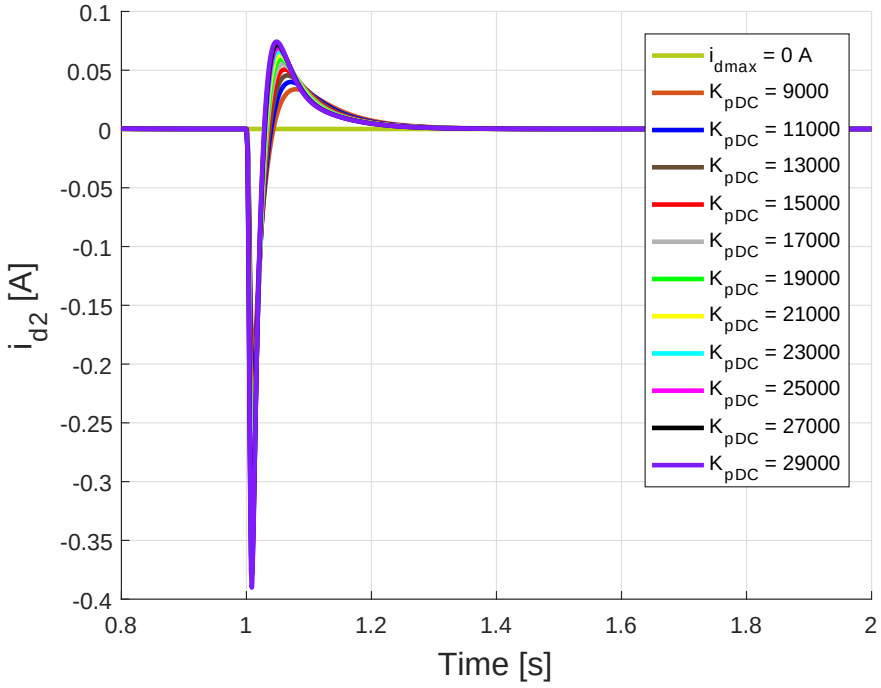

Figure A.138: Current i_{d2} from simulation 5 of Case 1

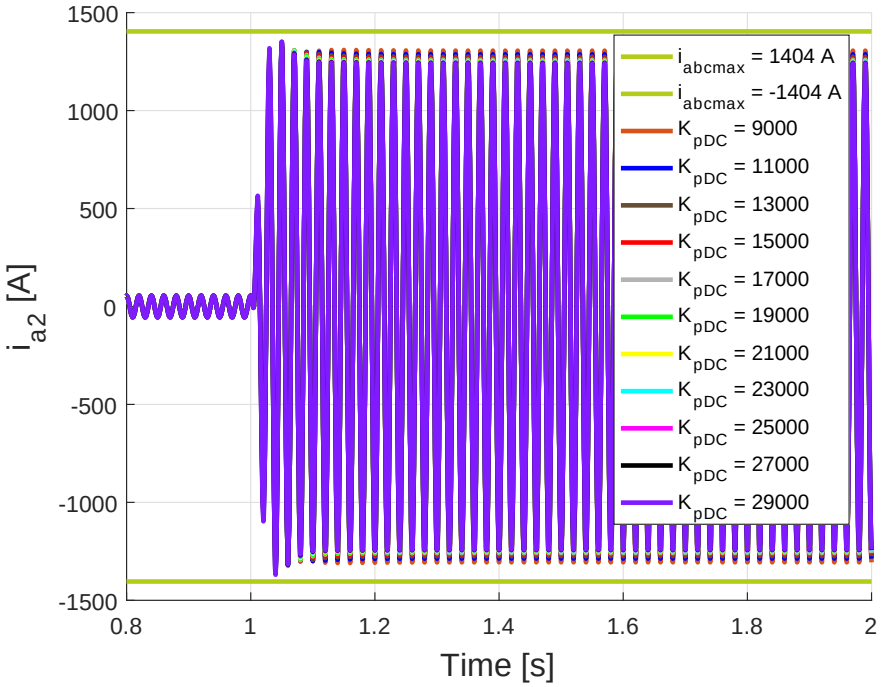

Figure A.139: Current i_{a2} from simulation 5 of Case 1

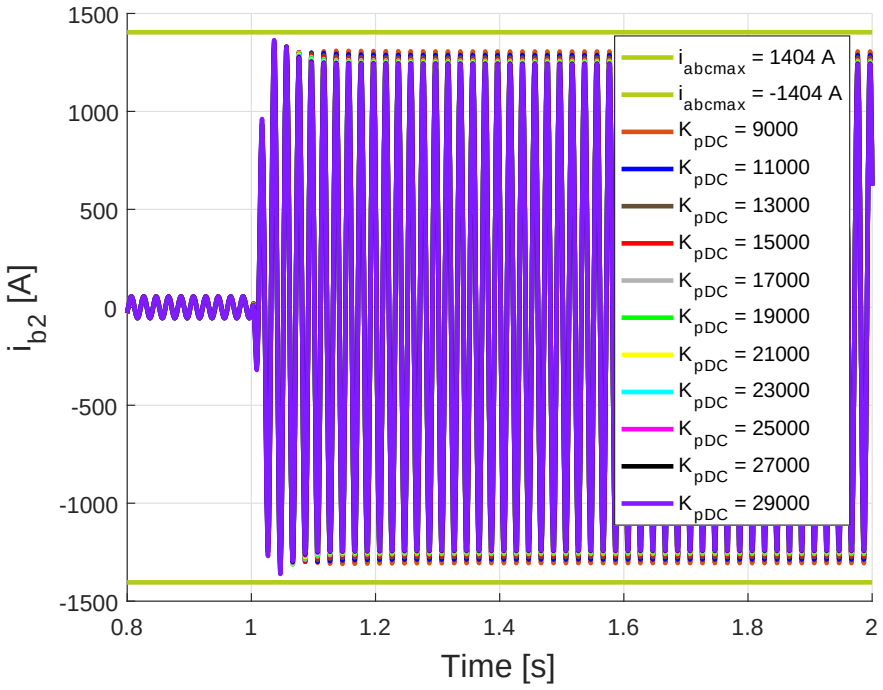

Figure A.140: Current i_{b2} from simulation 5 of Case 1

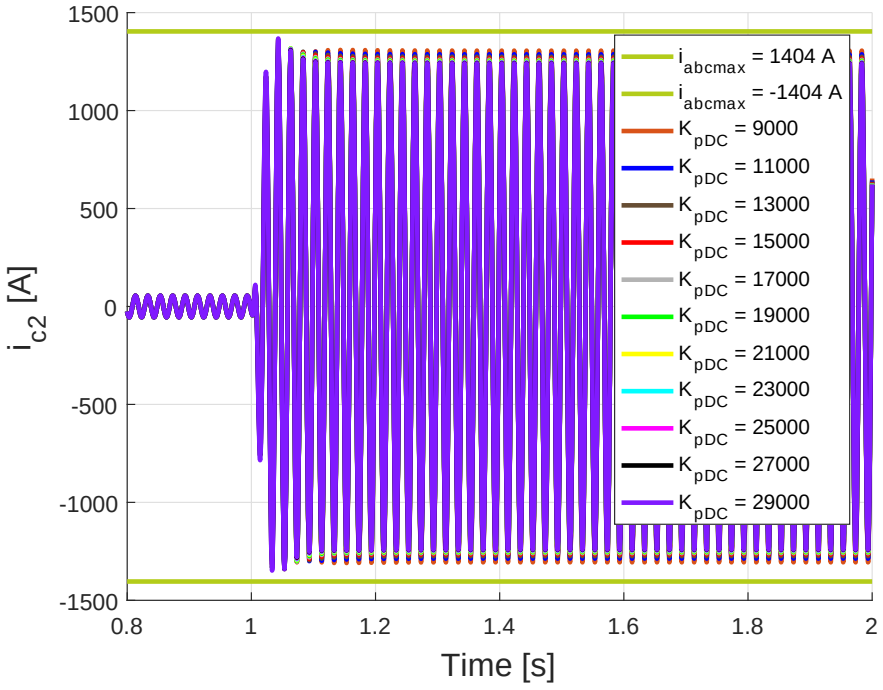

Figure A.141: Current i_{c2} from simulation 5 of Case 1

Annex B

Simulations of Case 2: Different proportional gains

The solver chosen for each simulation has been the ode4 (Runge-Kutta) with a fixed-step size of 10^{-5}.

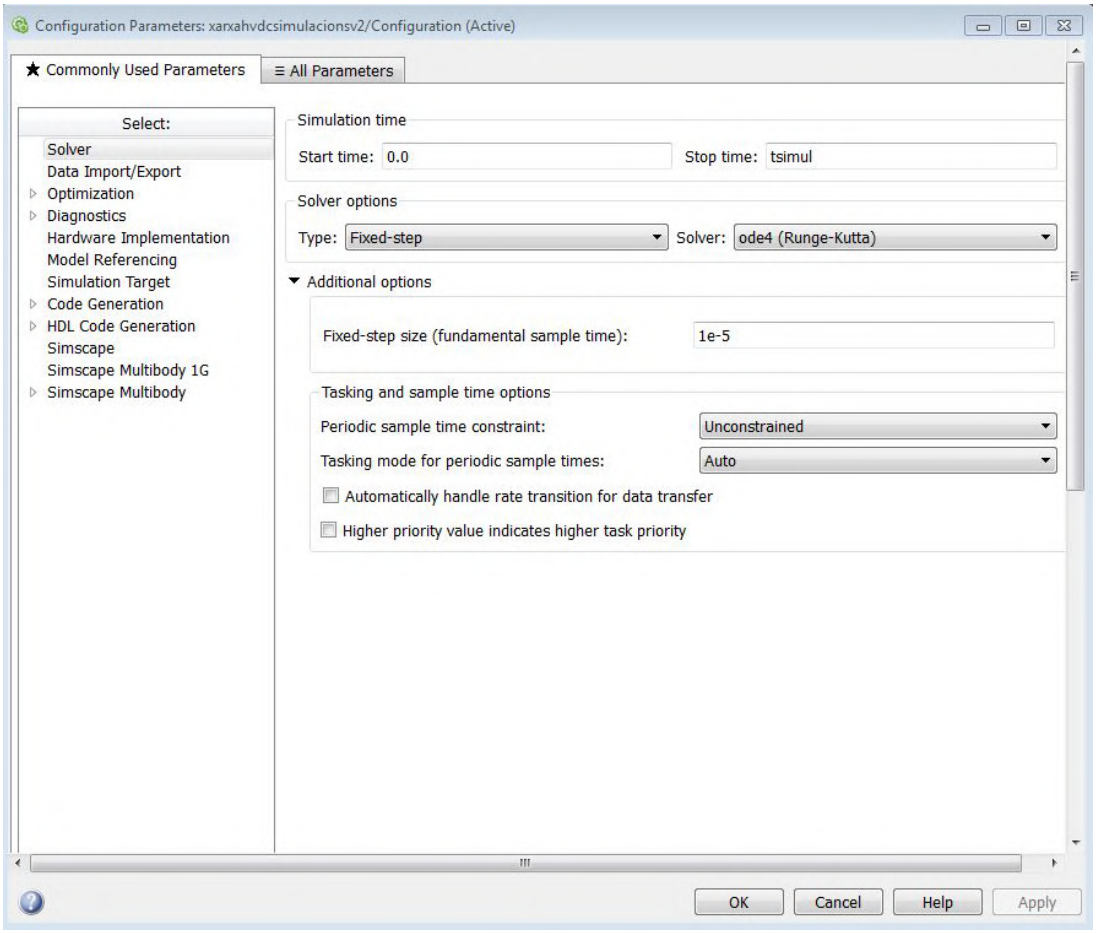

Figure B.1: Configuration parameters of the solver

B.1 Simulation 1

Simulation 1: $K_{pDC} \in [200, 1800]$ with a step of 200. In total 99 simulations for each electrical magnitude.

B.1.1 Voltages and currents of the multi-terminal HVDC grid

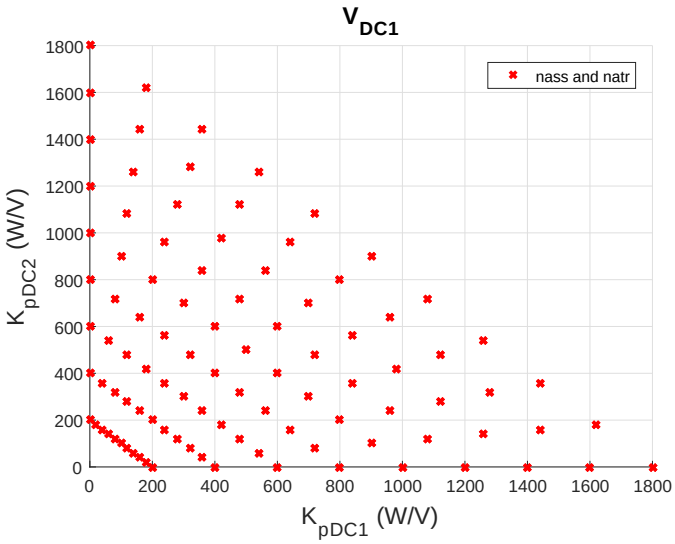

Figure B.2: Admissibility graph of voltage V_{DC1} from simulation 1 of Case 2

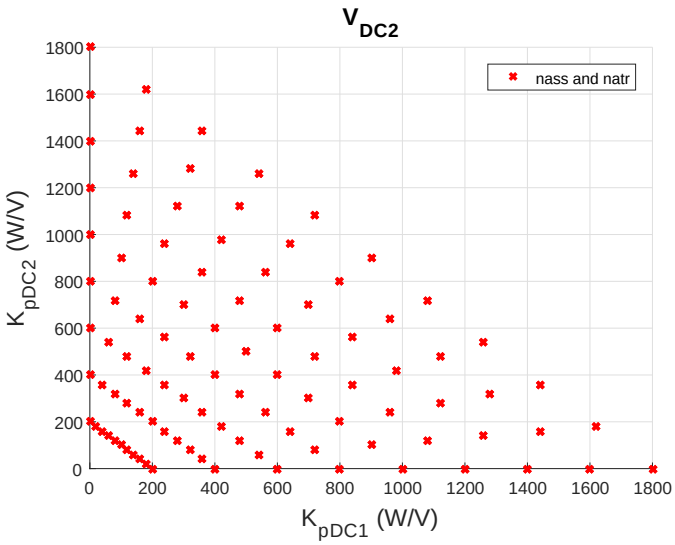

Figure B.3: Admissibility graph of voltage V_{DC2} from simulation 1 of Case 2

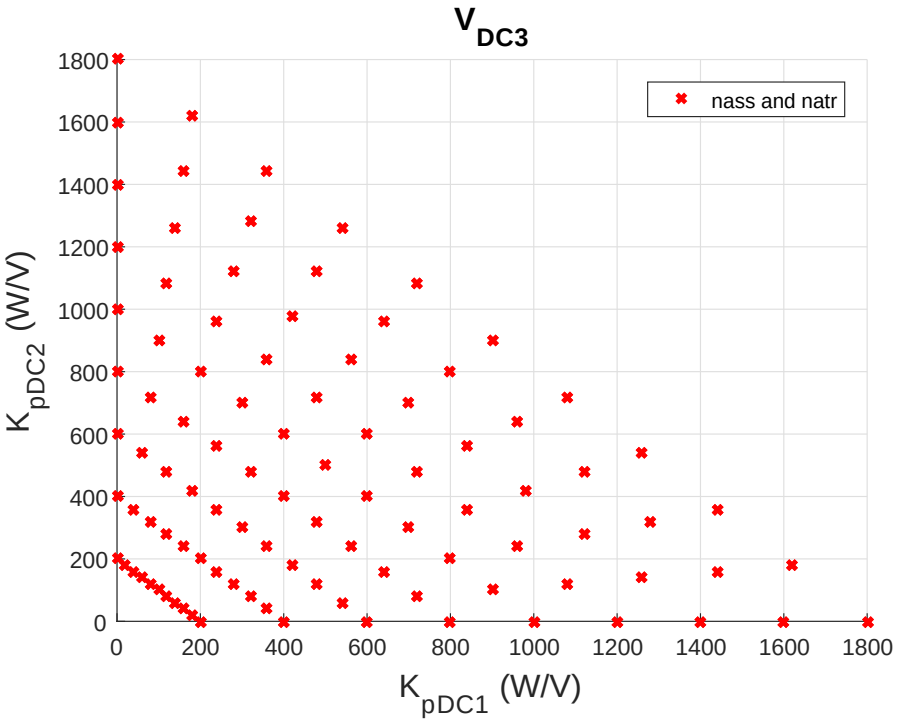

Figure B.4: Admissibility graph of voltage V_{DC3} from simulation 1 of Case 2

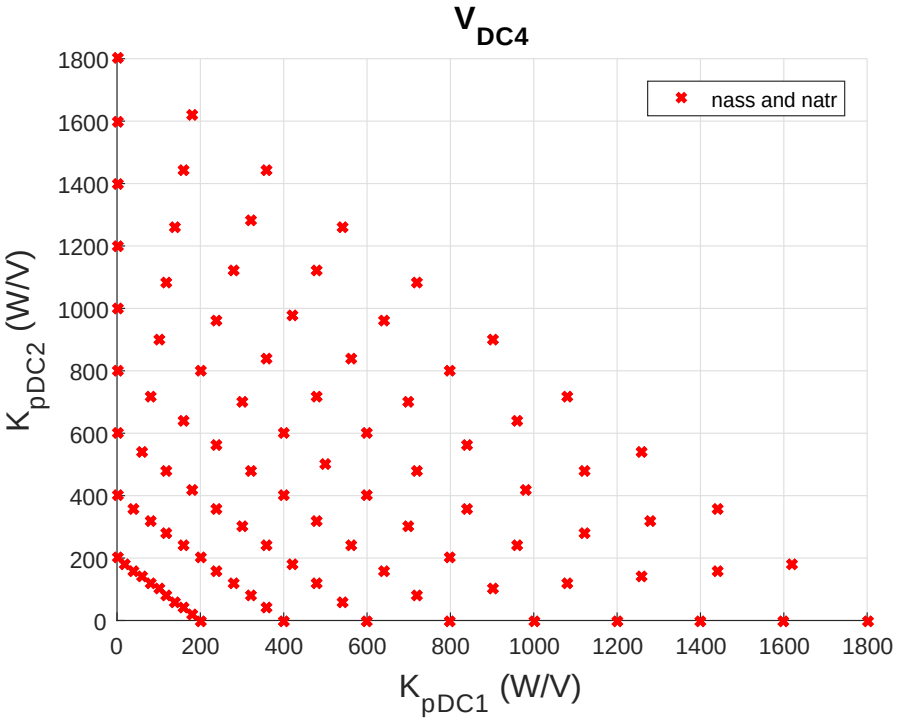

Figure B.5: Admissibility graph of voltage V_{DC4} from simulation 1 of Case 2

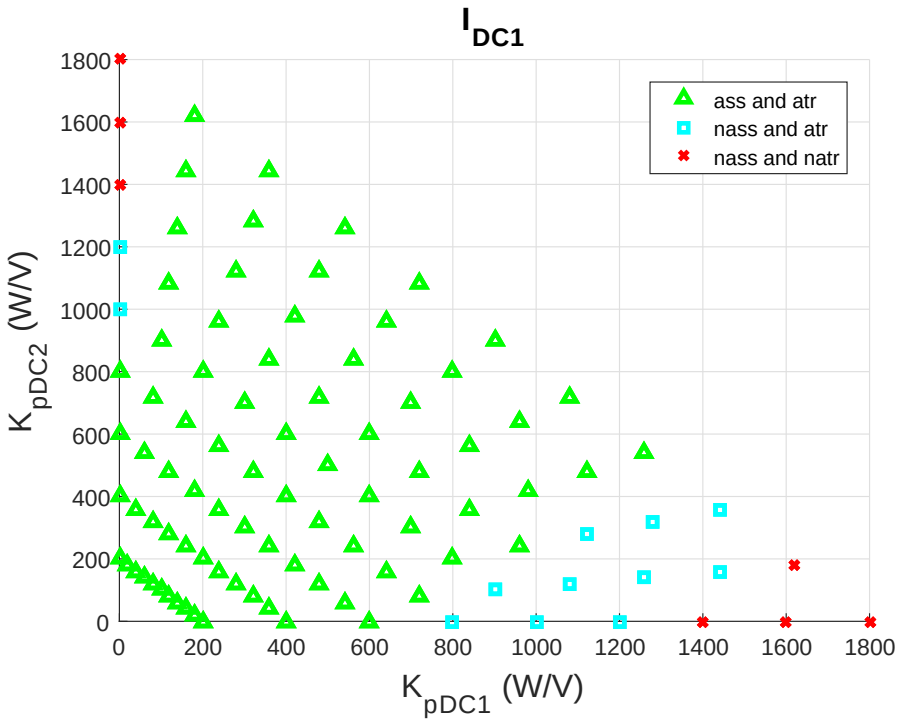

Figure B.6: Admissibility graph of current I_{DC1} from simulation 1 of Case 2

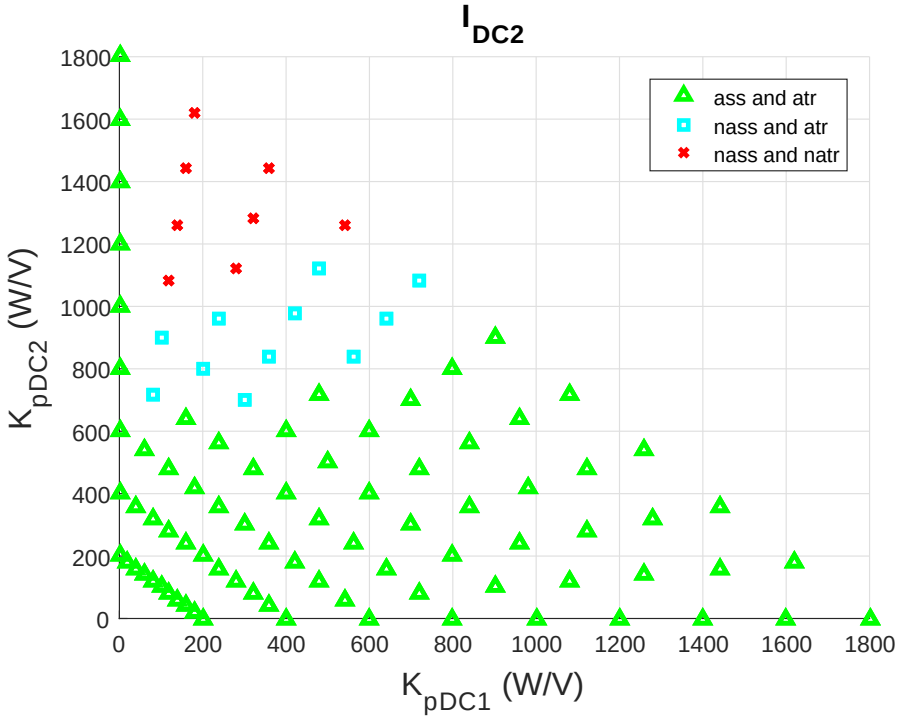

Figure B.7: Admissibility graph of current I_{DC2} from simulation 1 of Case 2

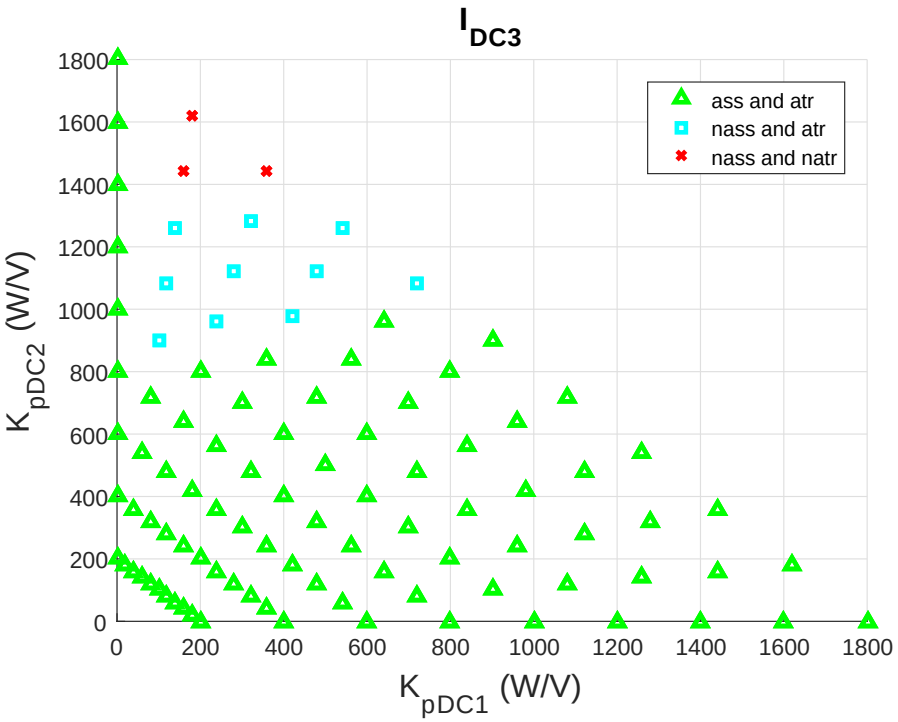

Figure B.8: Admissibility graph of current I_{DC3} from simulation 1 of Case 2

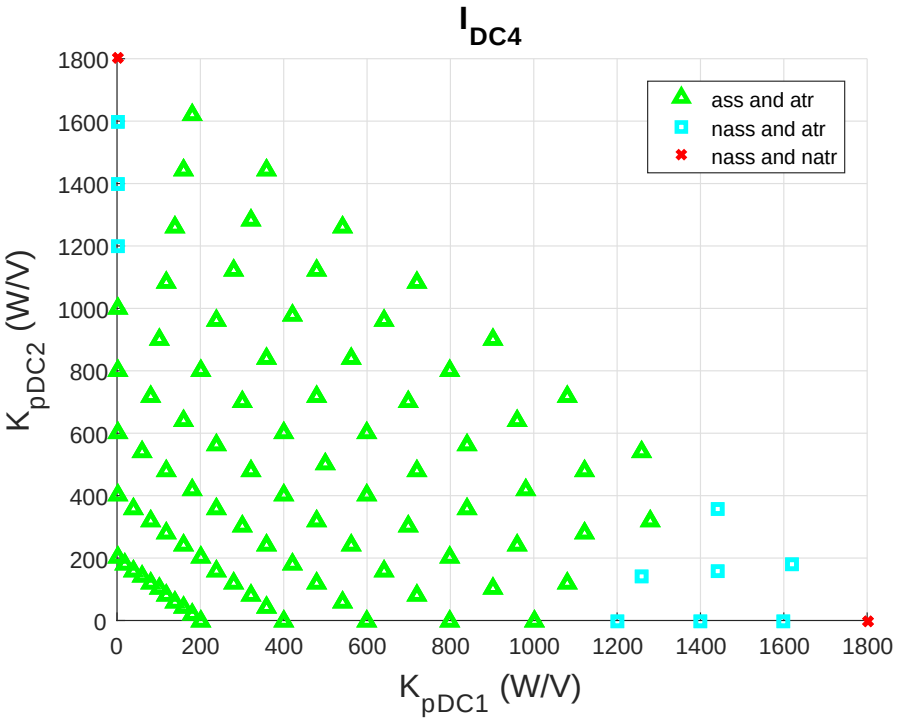

Figure B.9: Admissibility graph of current I_{DC4} from simulation 1 of Case 2

B.1.2 Voltages and currents of power converter 1

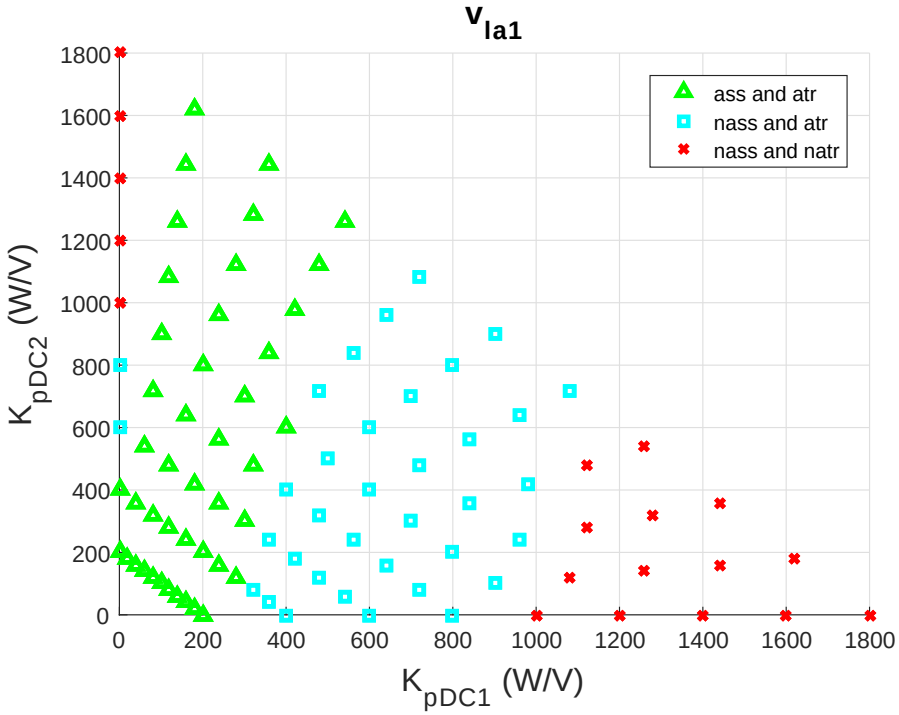

Figure B.10: Admissibility graph of voltage v_{la1} from simulation 1 of Case 2

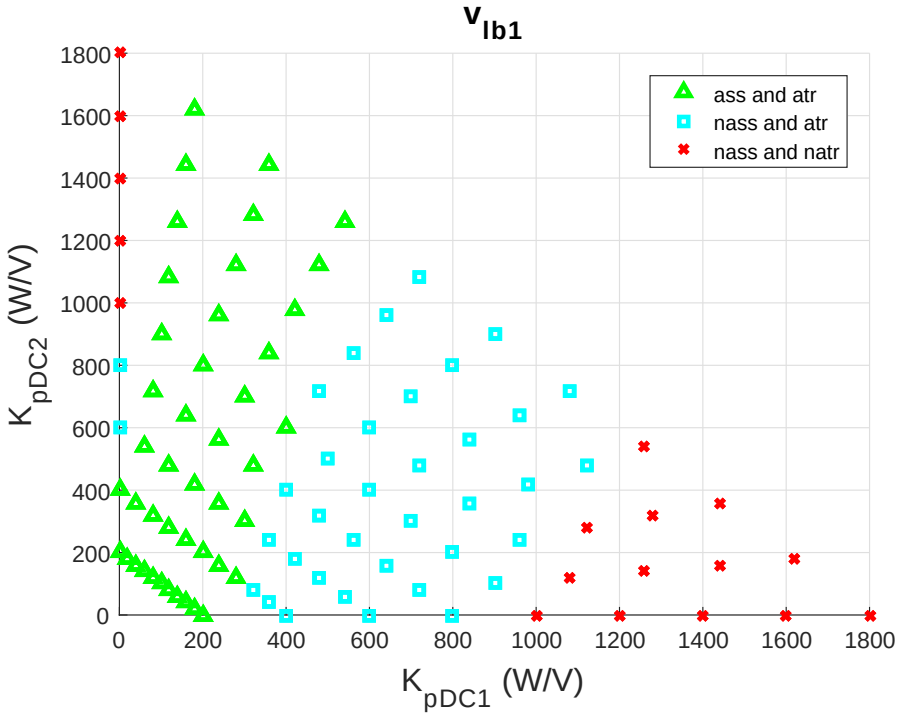

Figure B.11: Admissibility graph of voltage v_{lb1} from simulation 1 of Case 2

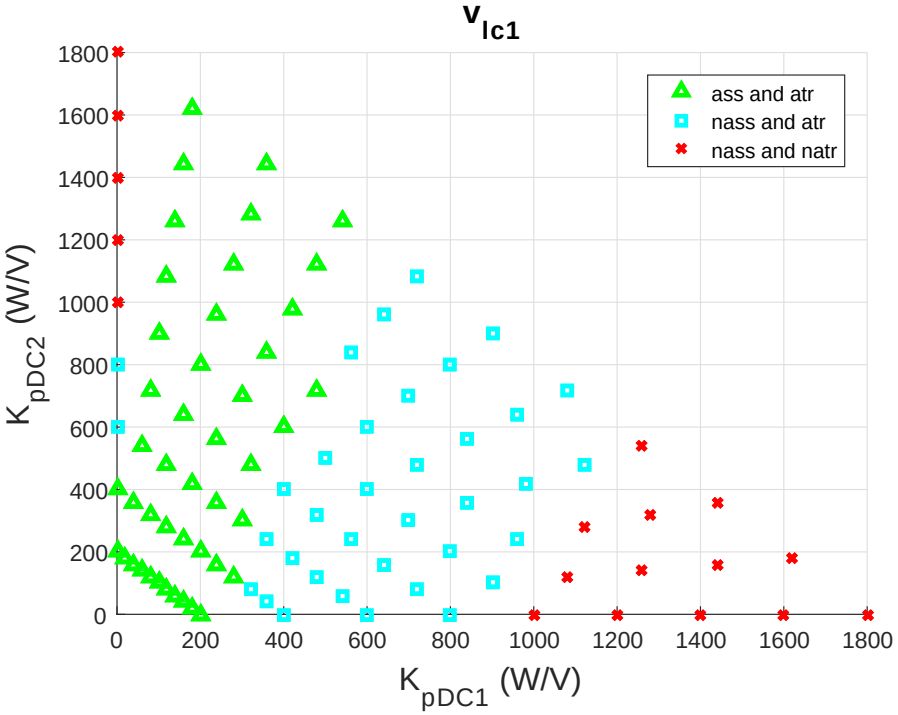

Figure B.12: Admissibility graph of voltage v_{lc1} from simulation 1 of Case 2

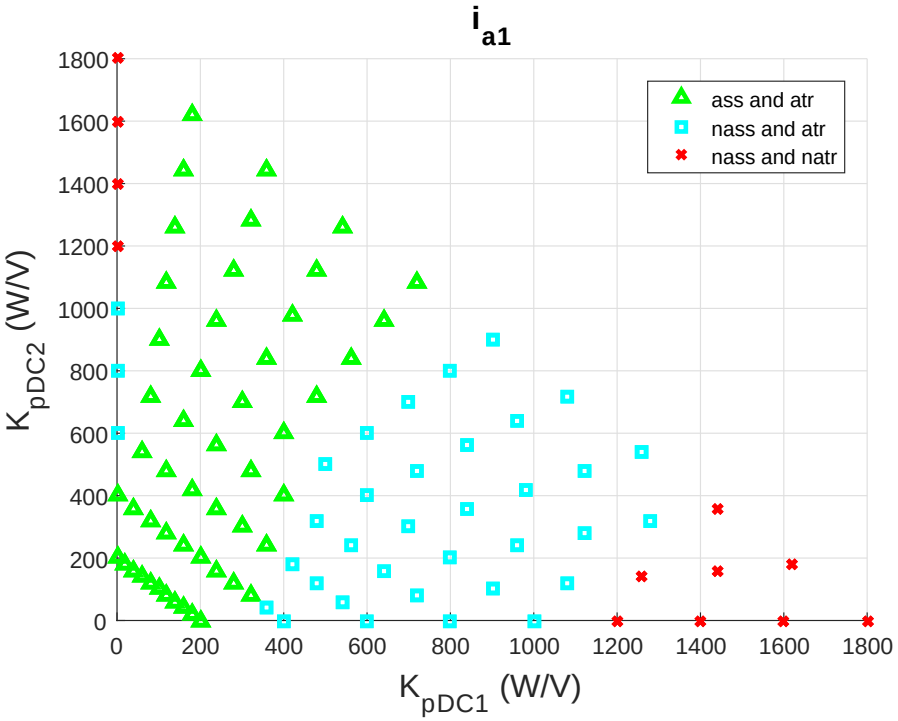

Figure B.13: Admissibility graph of current i_{a1} from simulation 1 of Case 2

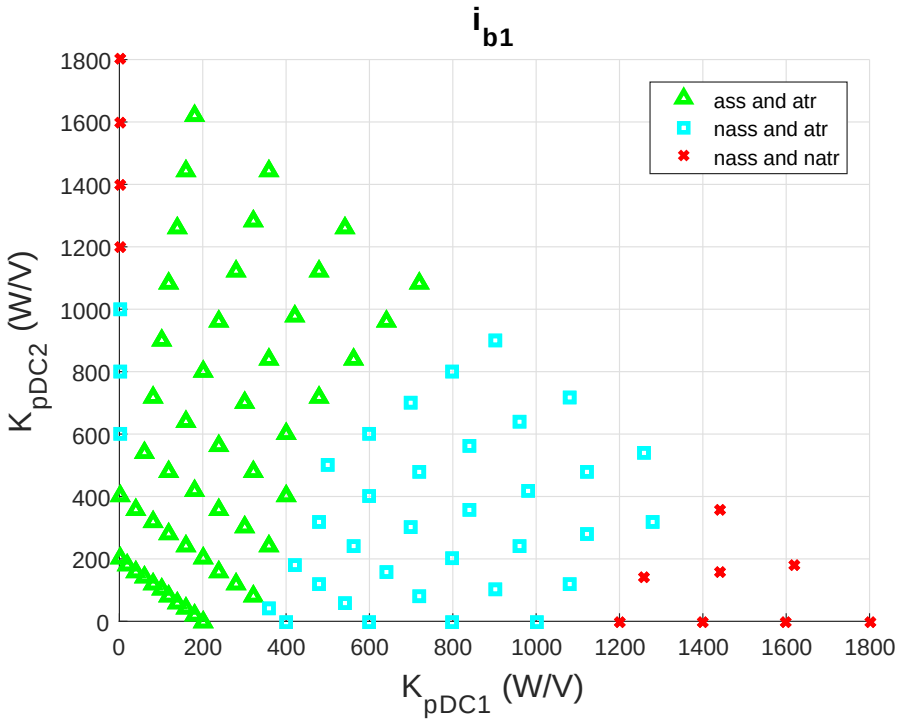

Figure B.14: Admissibility graph of current i_{b1} from simulation 1 of Case 2

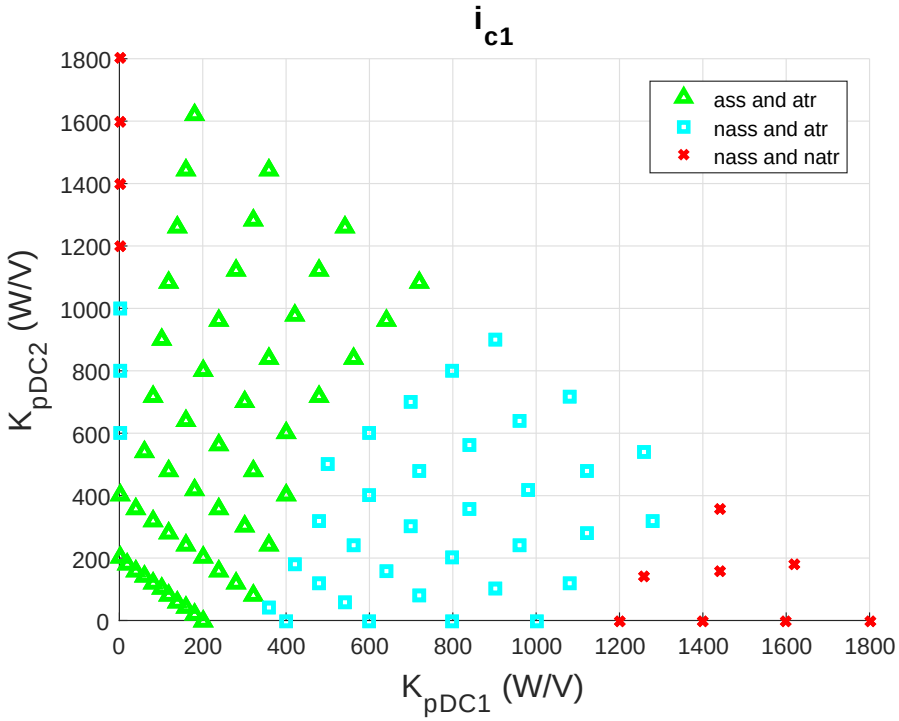

Figure B.15: Admissibility graph of current i_{c1} from simulation 1 of Case 2

B.1.3 Voltages and currents of power converter 2

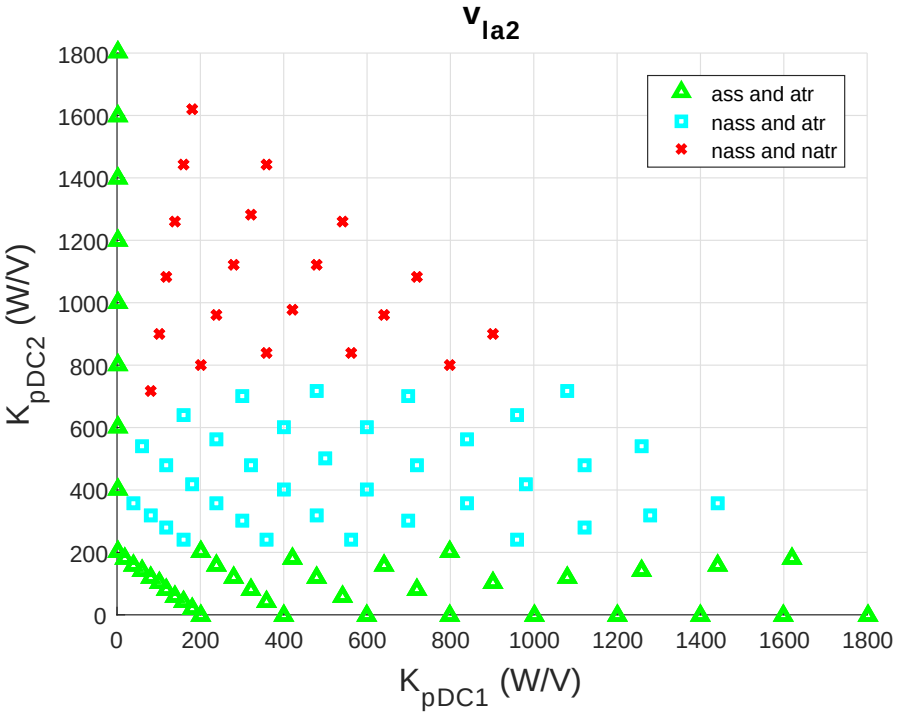

Figure B.16: Admissibility graph of voltage v_{la2} from simulation 1 of Case 2

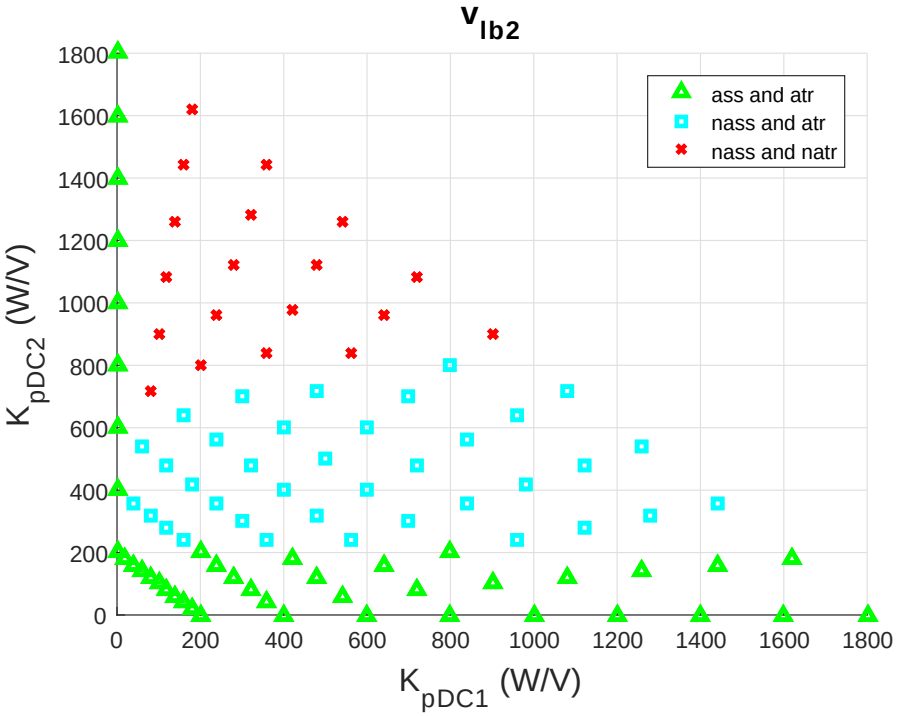

Figure B.17: Admissibility graph of voltage v_{lb2} from simulation 1 of Case 2

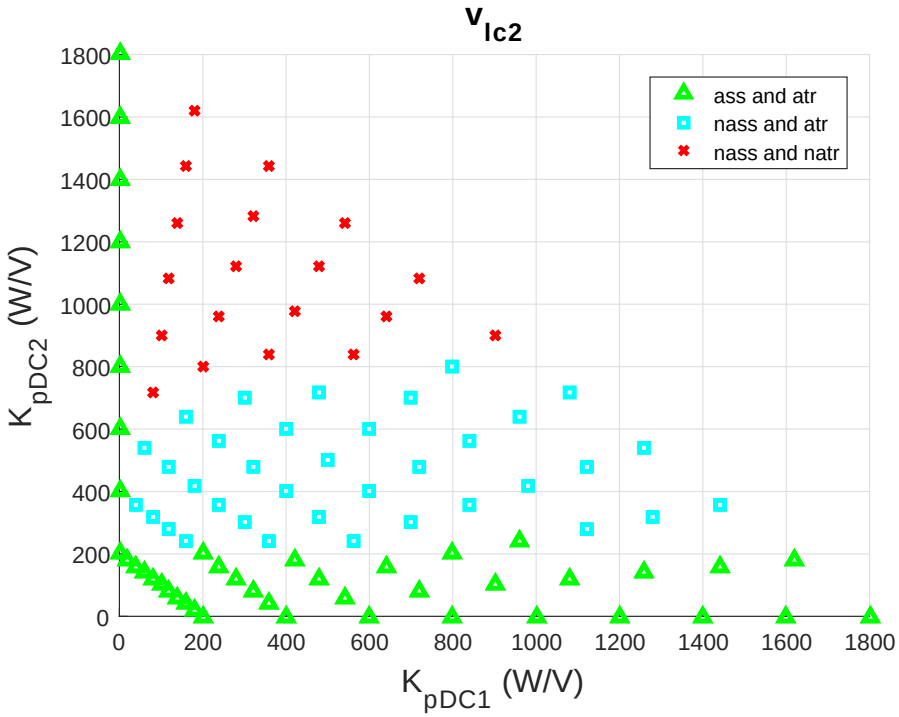

Figure B.18: Admissibility graph of voltage v_{lc2} from simulation 1 of Case 2

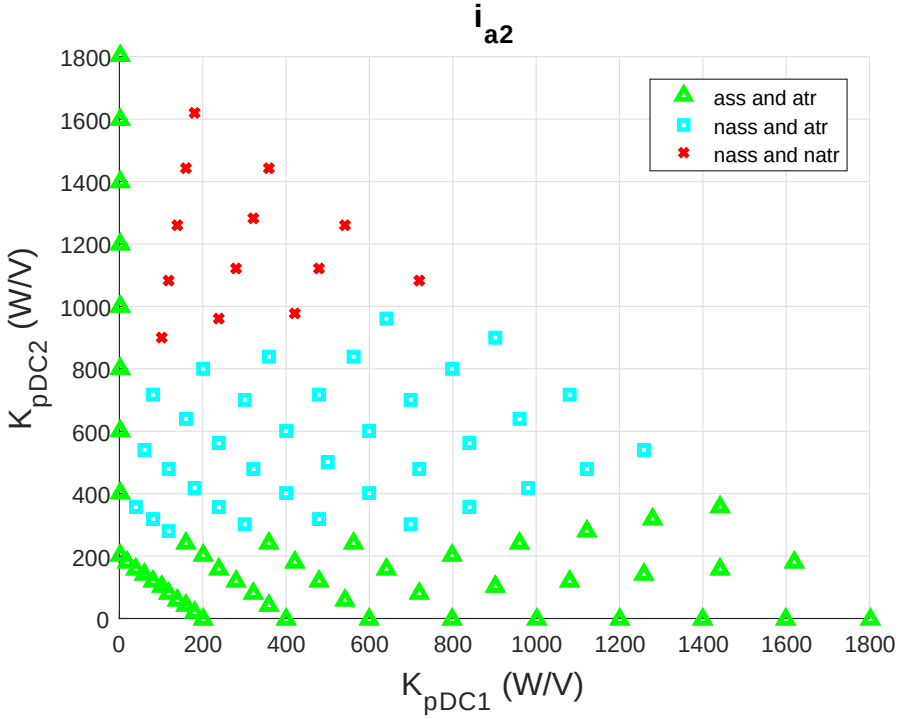

Figure B.19: Admissibility graph of current i_{a2} from simulation 1 of Case 2

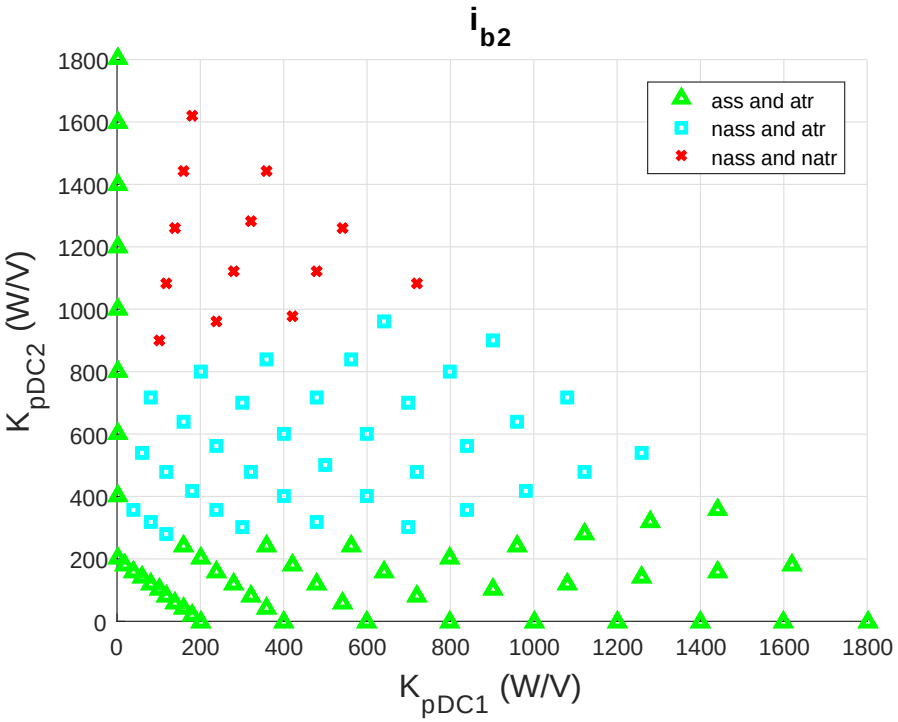

Figure B.20: Admissibility graph of current i_{b2} from simulation 1 of Case 2

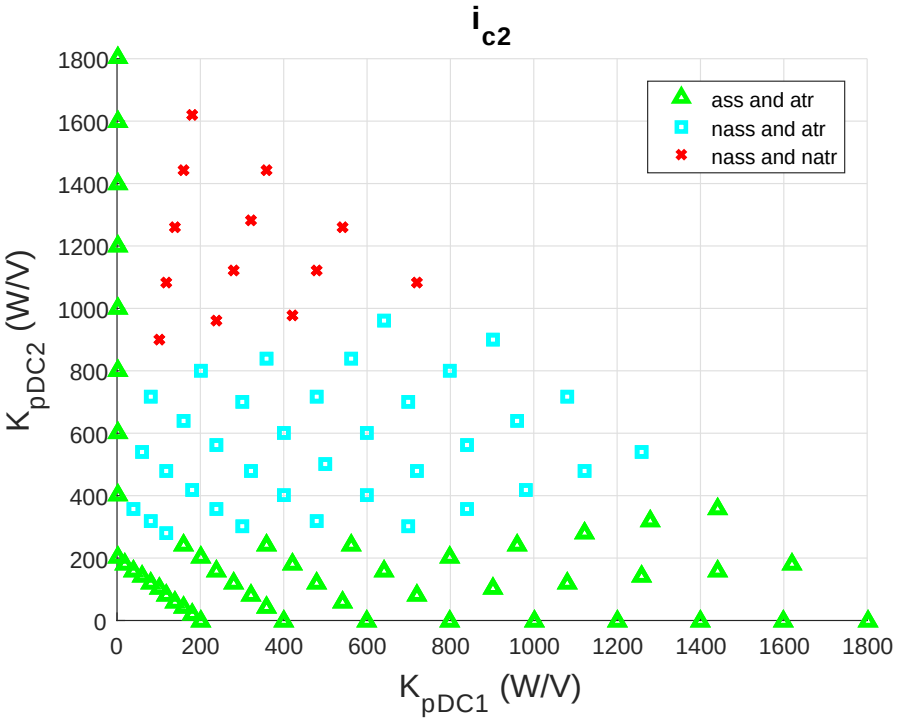

Figure B.21: Admissibility graph of current i_{c2} from simulation 1 of Case 2

B.2 Simulation 2

Simulation 2: $K_{pDC} \in [2000, 10000]$ with a step of 1000. In total 99 simulations for each electrical magnitude.

B.2.1 Voltages and currents of the multi-terminal HVDC grid

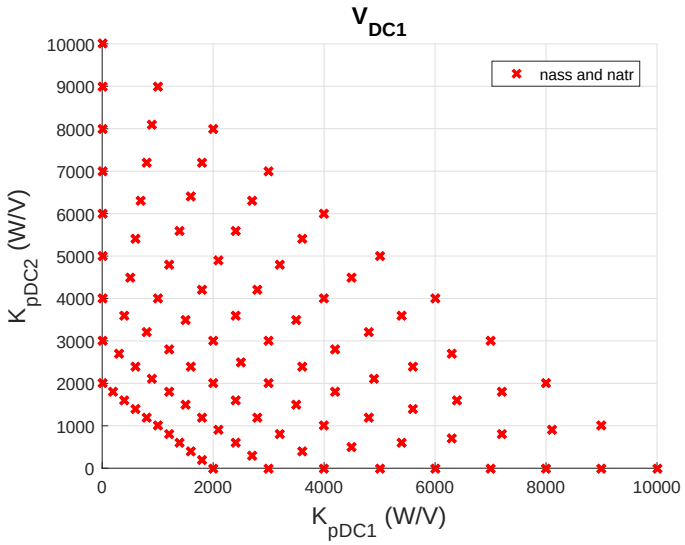

Figure B.22: Admissibility graph of voltage V_{DC1} from simulation 2 of Case 2

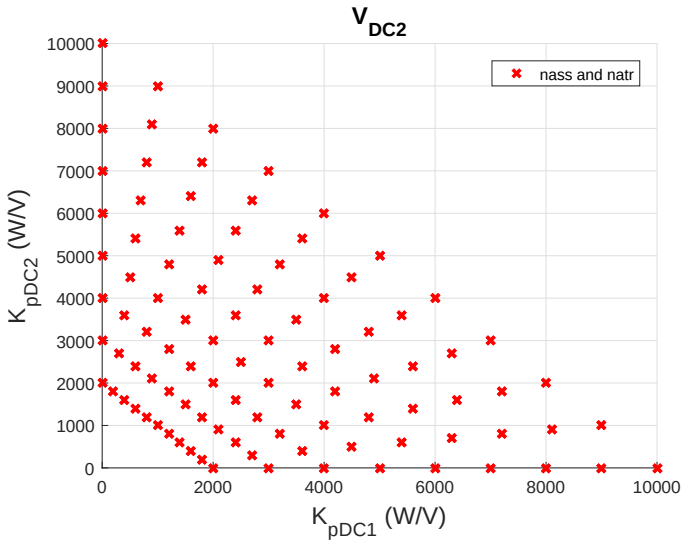

Figure B.23: Admissibility graph of voltage V_{DC2} from simulation 2 of Case 2

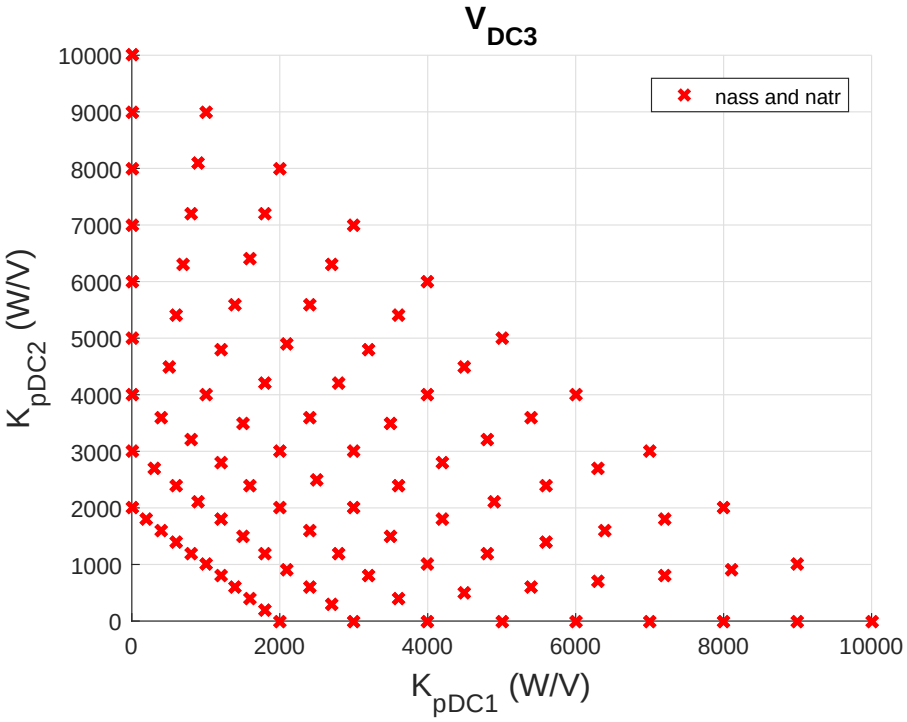

Figure B.24: Admissibility graph of voltage V_{DC3} from simulation 2 of Case 2

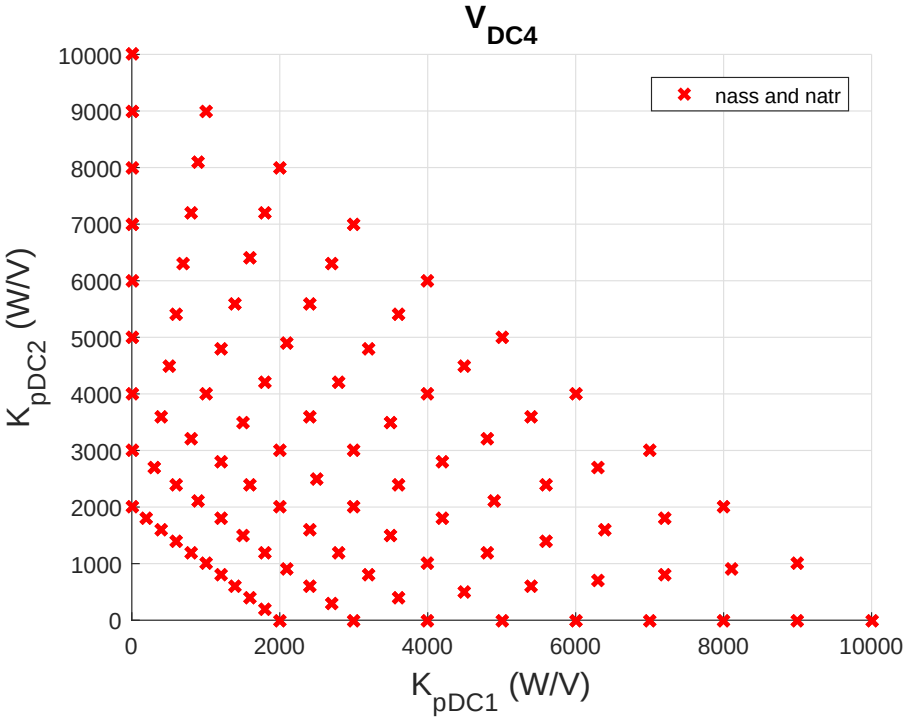

Figure B.25: Admissibility graph of voltage V_{DC4} from simulation 2 of Case 2

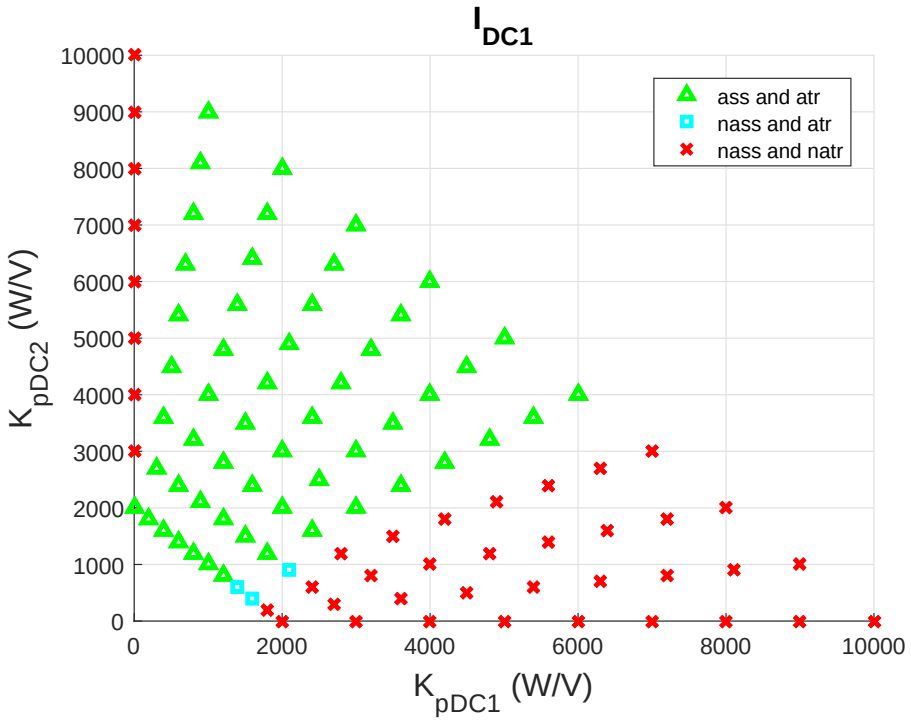

Figure B.26: Admissibility graph of current I_{DC1} from simulation 2 of Case 2

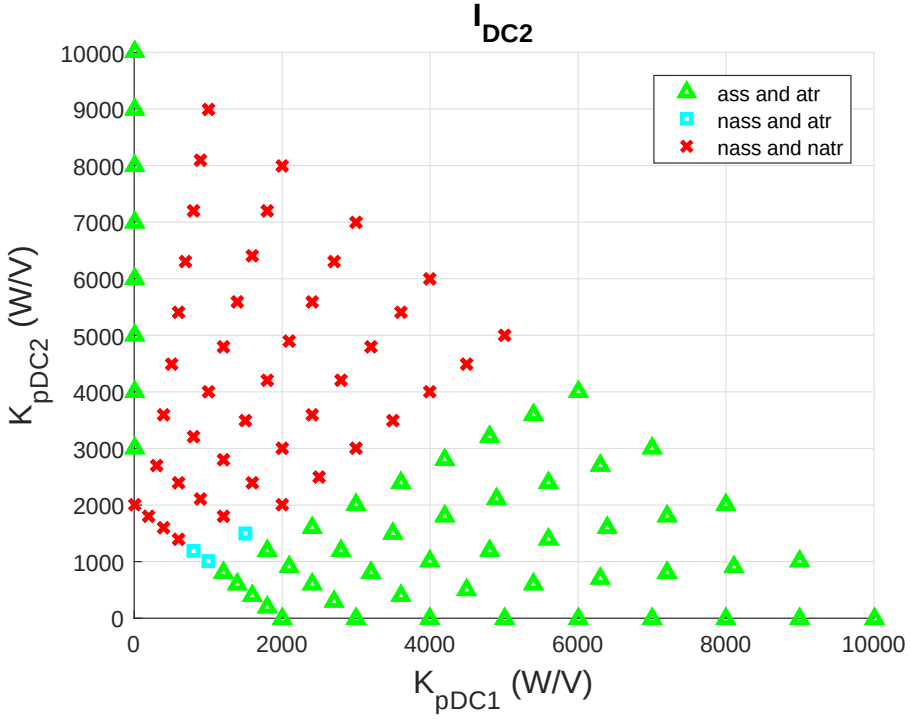

Figure B.27: Admissibility graph of current I_{DC2} from simulation 2 of Case 2

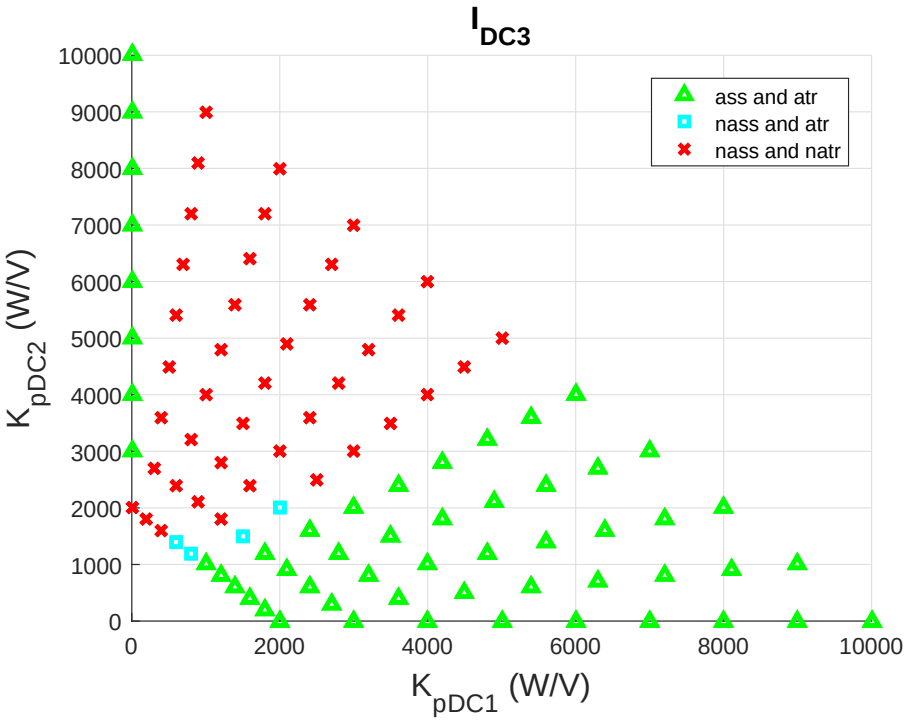

Figure B.28: Admissibility graph of current I_{DC3} from simulation 2 of Case 2

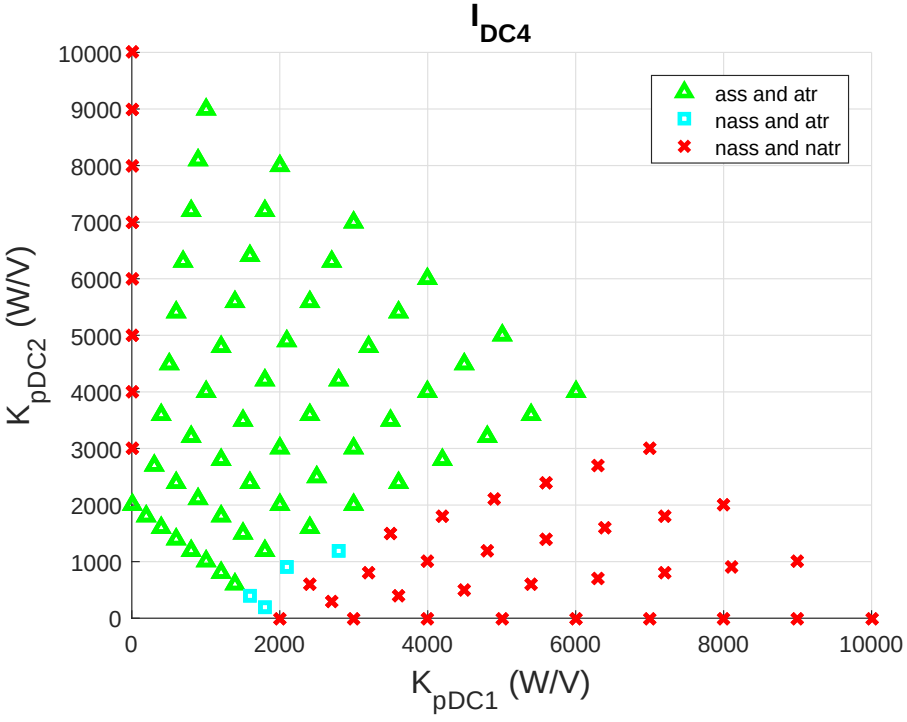

Figure B.29: Admissibility graph of current I_{DC4} from simulation 2 of Case 2

B.2.2 Voltages and currents of power converter 1

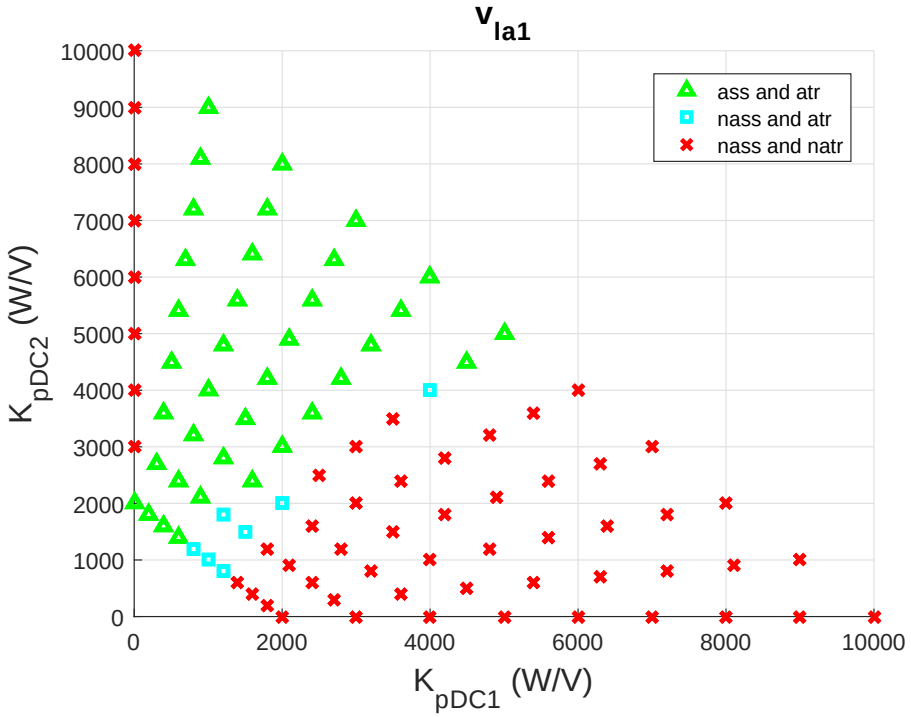

Figure B.30: Admissibility graph of voltage v_{la1} from simulation 2 of Case 2

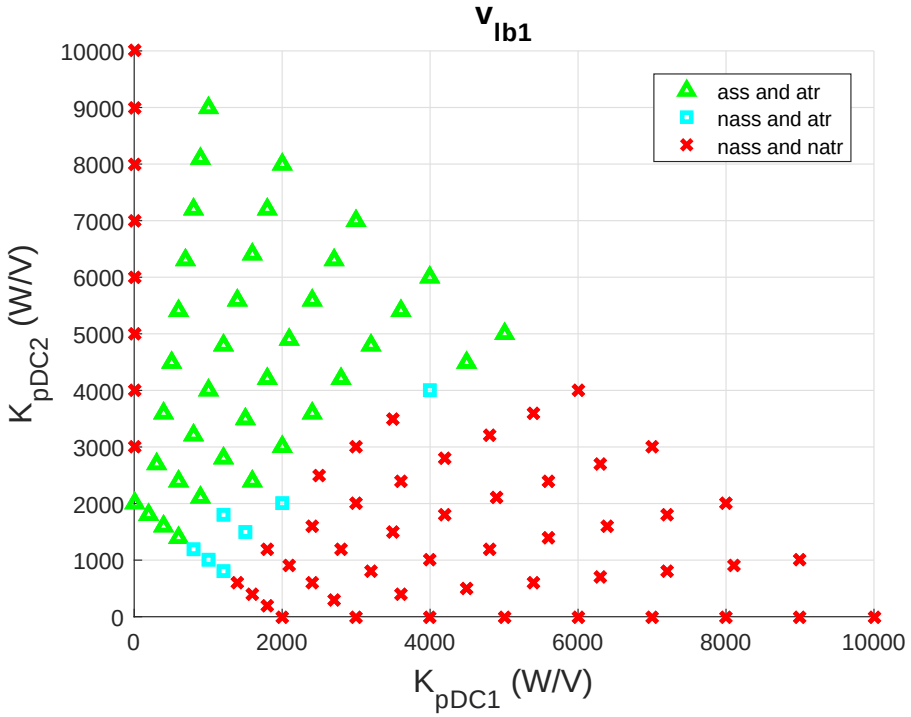

Figure B.31: Admissibility graph of voltage v_{lb1} from simulation 2 of Case 2

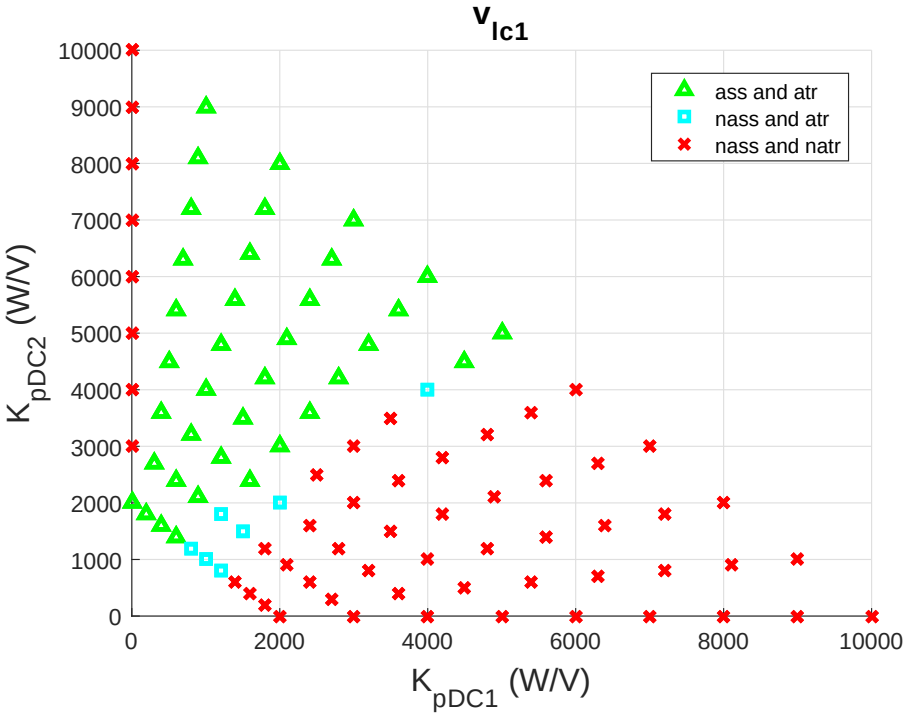

Figure B.32: Admissibility graph of voltage v_{lc1} from simulation 2 of Case 2

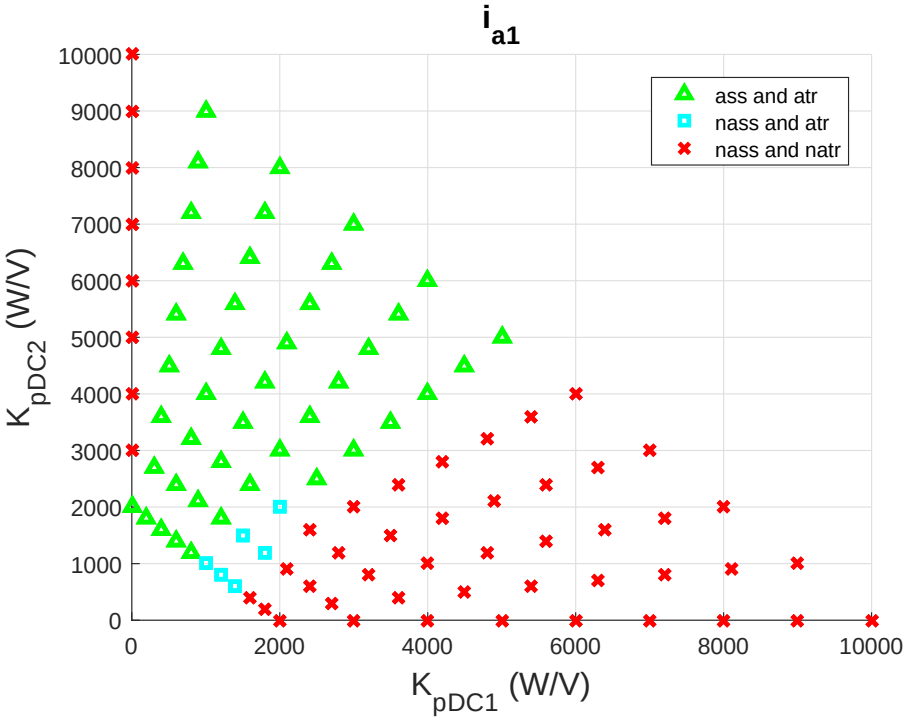

Figure B.33: Admissibility graph of current i_{a1} from simulation 2 of Case 2

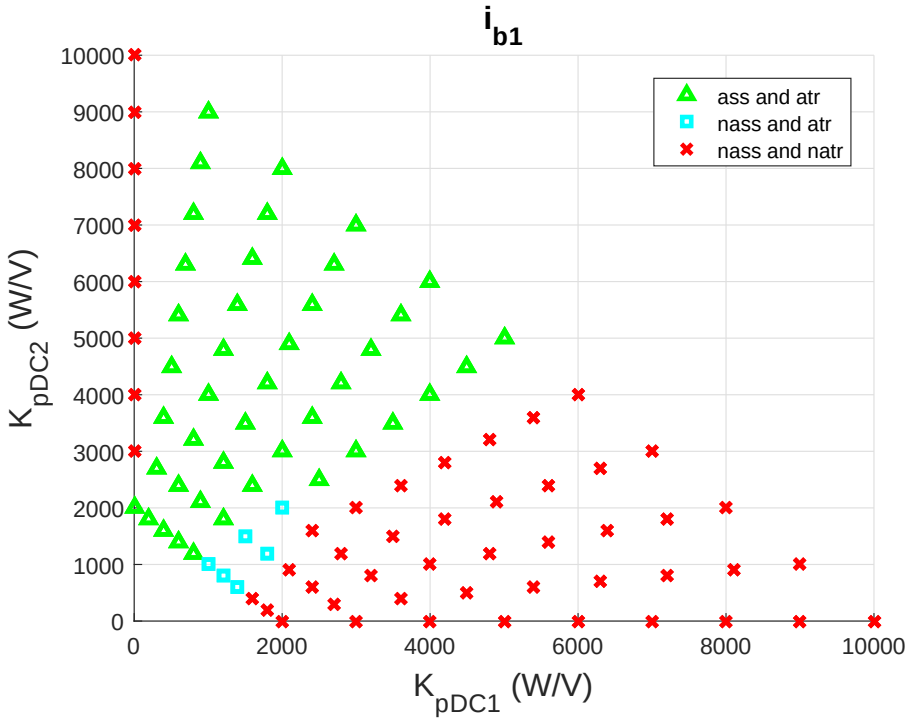

Figure B.34: Admissibility graph of current i_{b1} from simulation 2 of Case 2

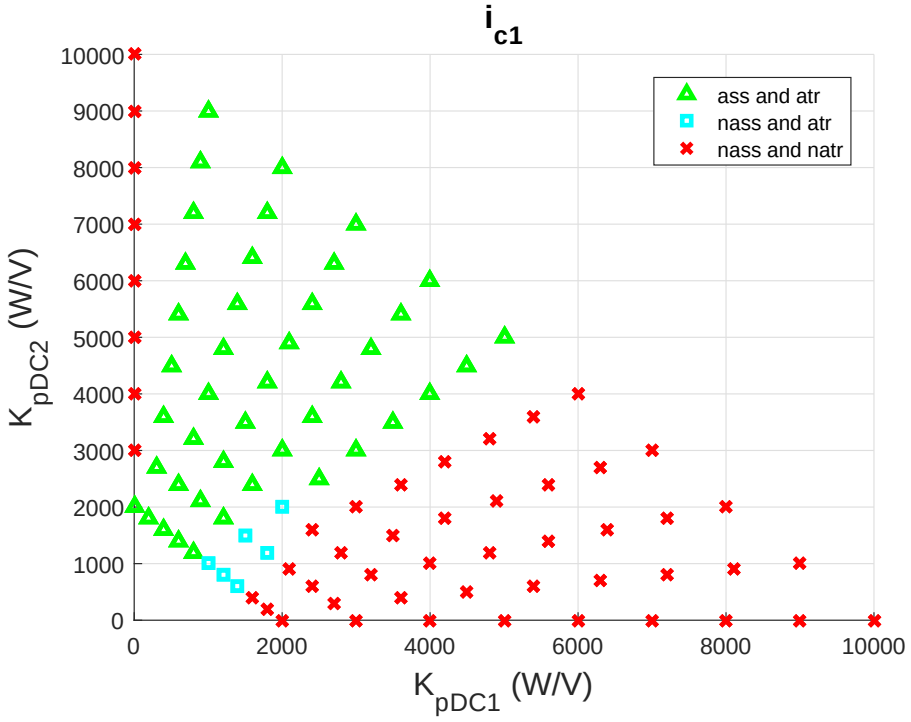

Figure B.35: Admissibility graph of current i_{c1} from simulation 2 of Case 2

B.2.3 Voltages and currents of power converter 2

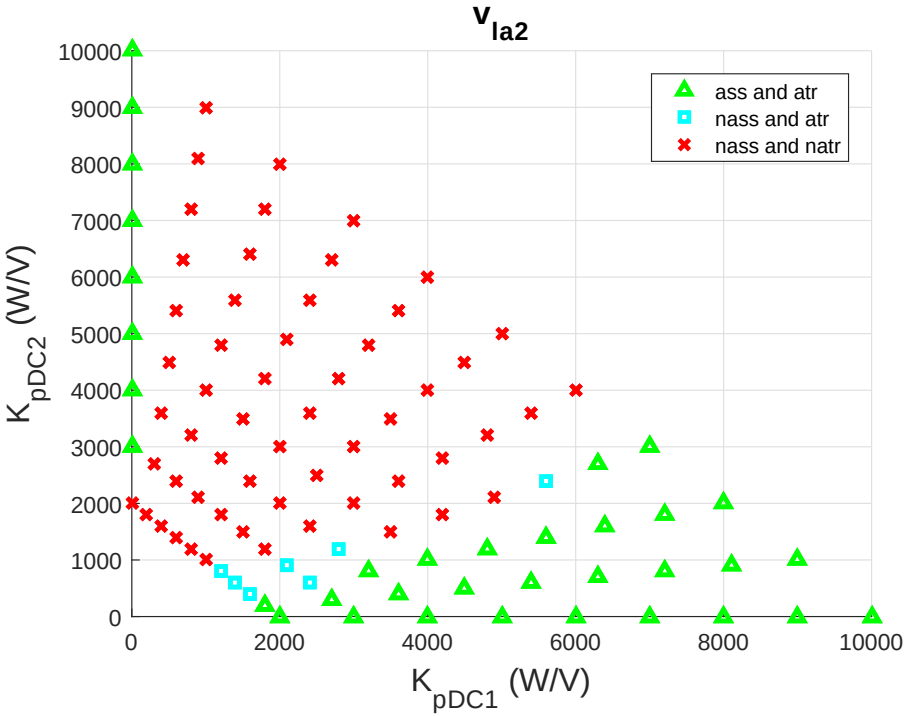

Figure B.36: Admissibility graph of voltage v_{la2} from simulation 2 of Case 2

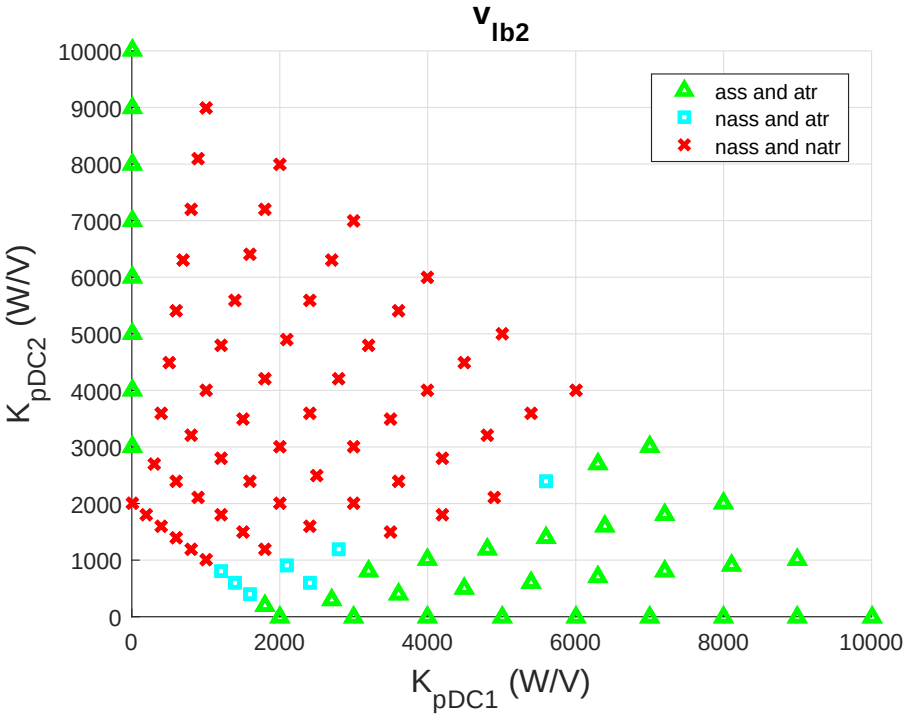

Figure B.37: Admissibility graph of voltage v_{lb2} from simulation 2 of Case 2

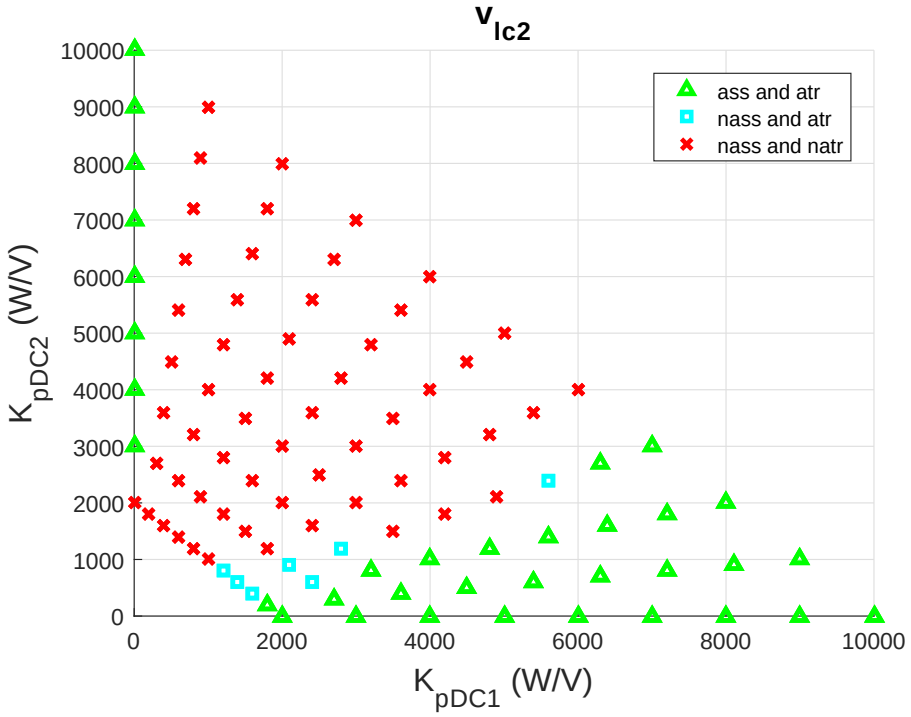

Figure B.38: Admissibility graph of voltage v_{lc2} from simulation 2 of Case 2

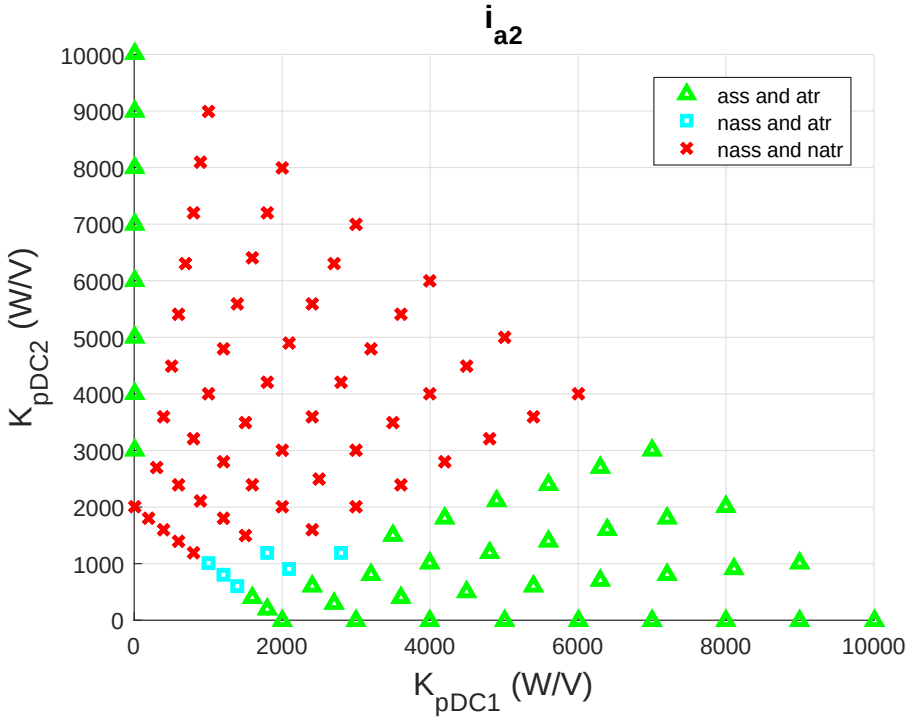

Figure B.39: Admissibility graph of current i_{a2} from simulation 2 of Case 2

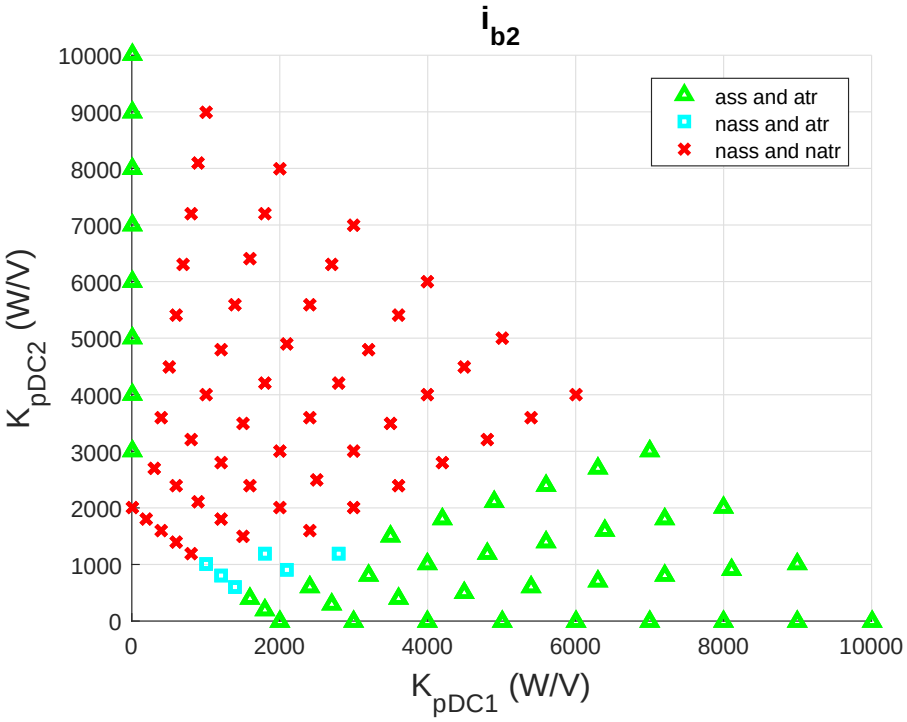

Figure B.40: Admissibility graph of current i_{b2} from simulation 2 of Case 2

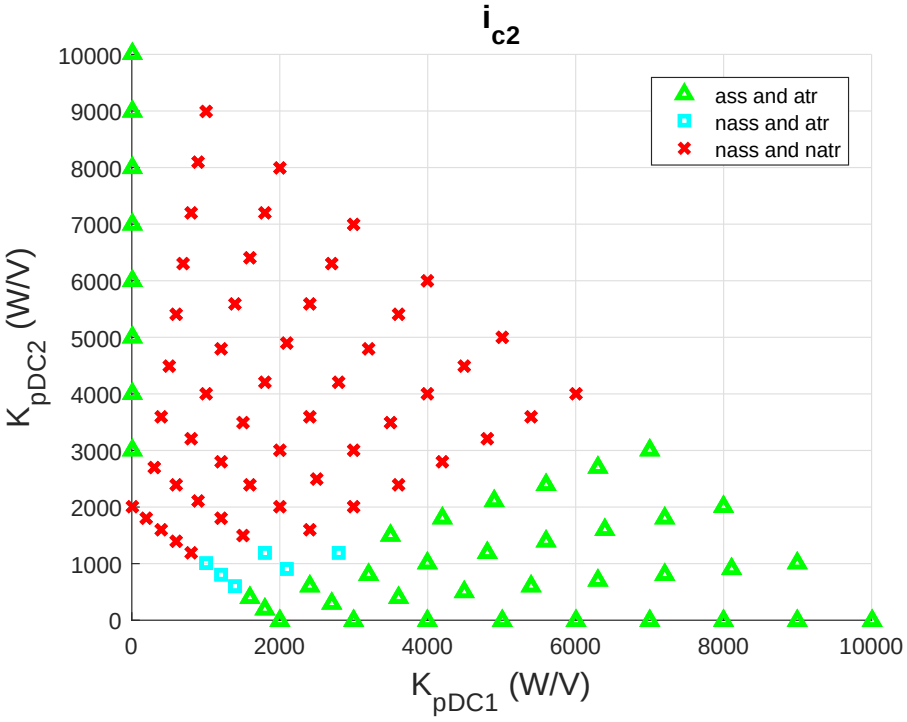

Figure B.41: Admissibility graph of current i_{c2} from simulation 2 of Case 2

B.3 Simulation 3

Simulation 3: $K_{pDC} \in [11000, 70000]$ with a step of 5900. In total 121 simulations for each electrical magnitude.

B.3.1 Voltages and currents of the multi-terminal HVDC grid

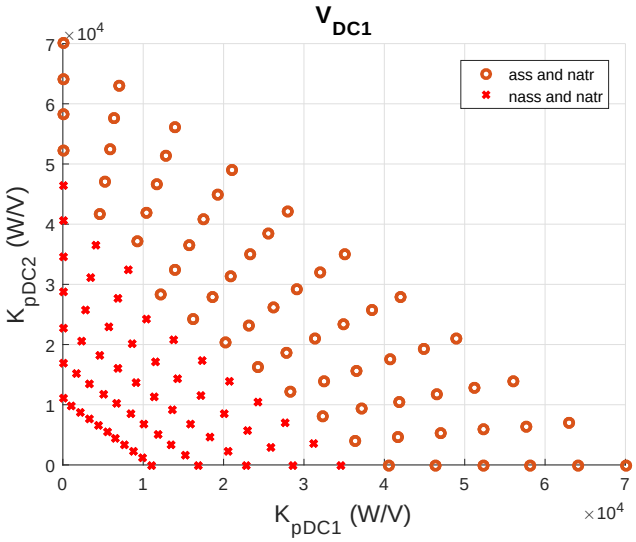

Figure B.42: Admissibility graph of voltage V_{DC1} from simulation 3 of Case 2

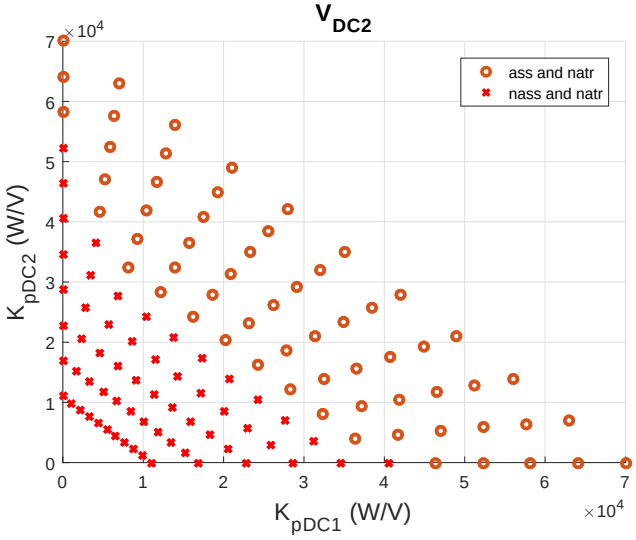

Figure B.43: Admissibility graph of voltage V_{DC2} from simulation 3 of Case 2

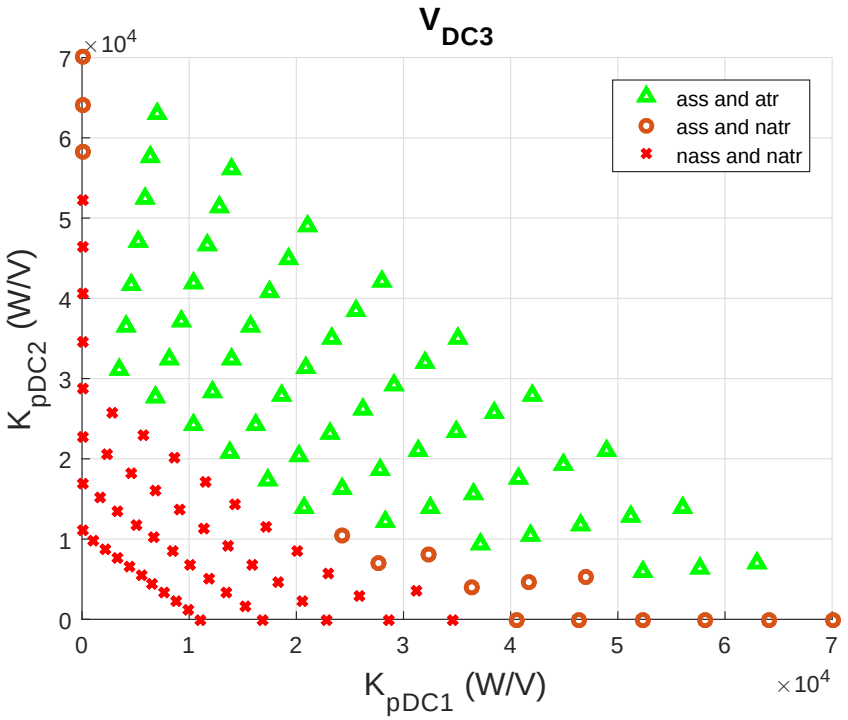

Figure B.44: Admissibility graph of voltage V_{DC3} from simulation 3 of Case 2

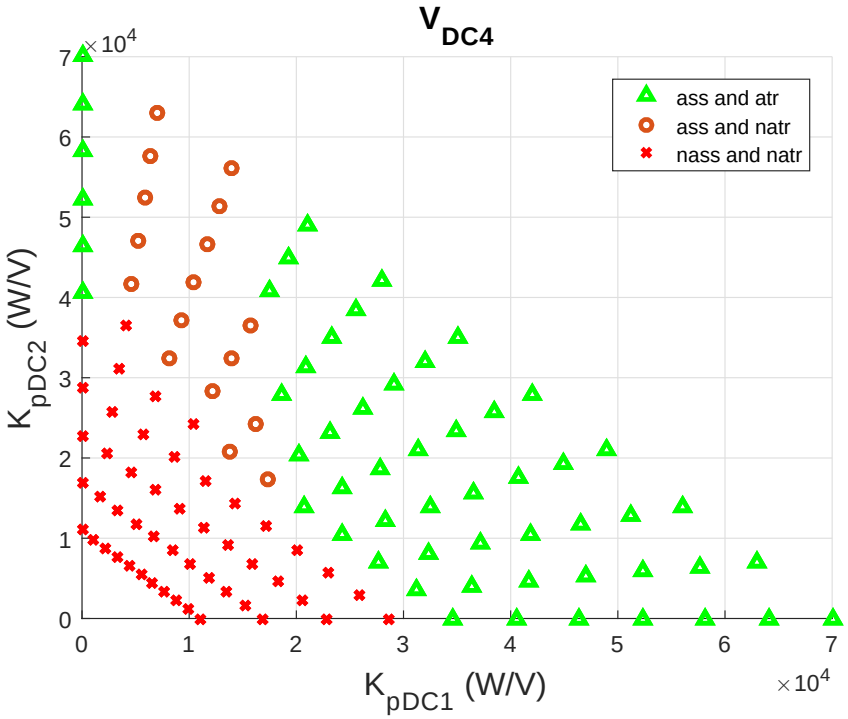

Figure B.45: Admissibility graph of voltage V_{DC4} from simulation 3 of Case 2

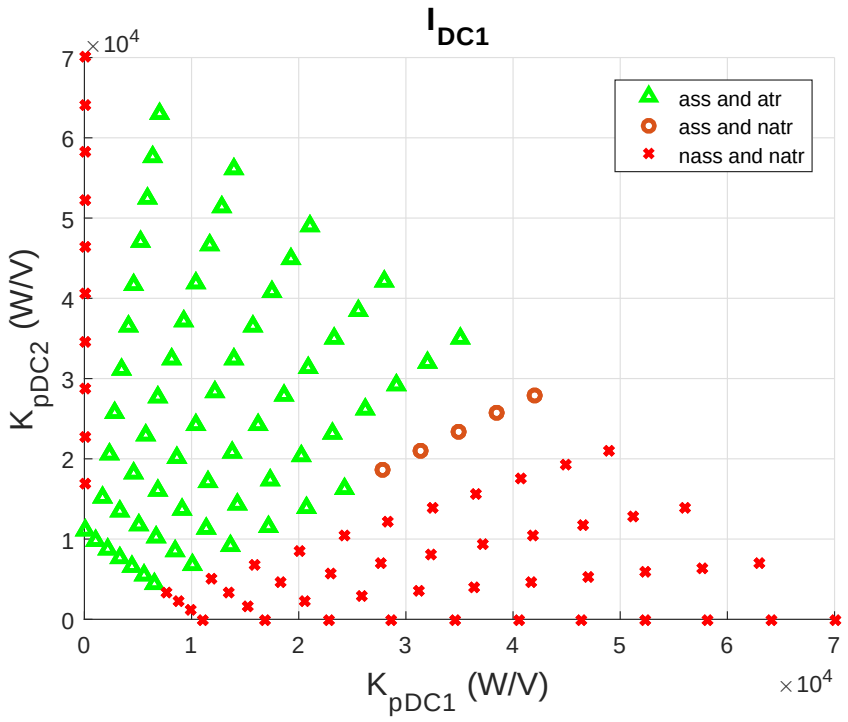

Figure B.46: Admissibility graph of current I_{DC1} from simulation 3 of Case 2

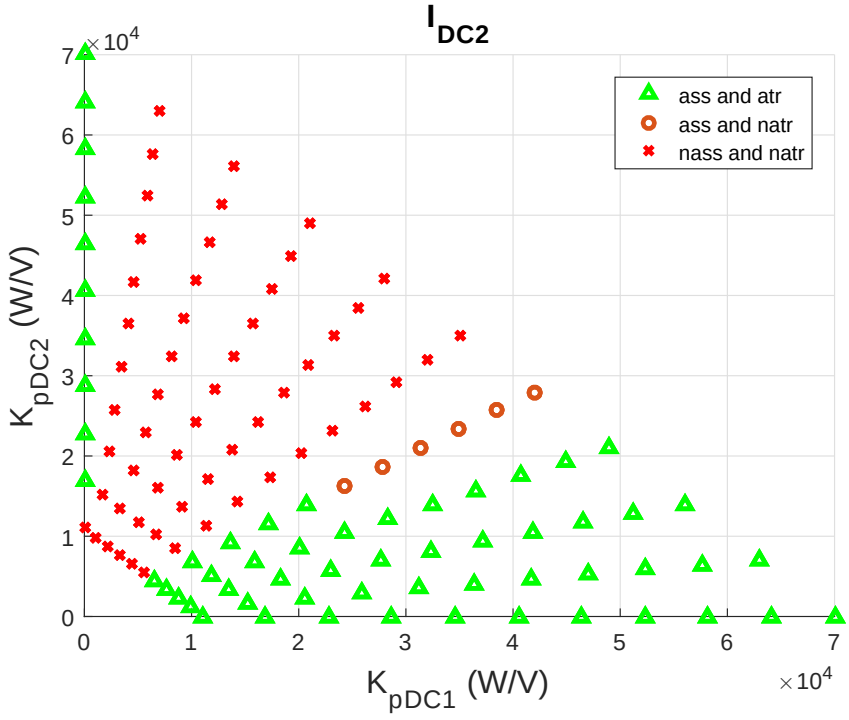

Figure B.47: Admissibility graph of current I_{DC2} from simulation 3 of Case 2

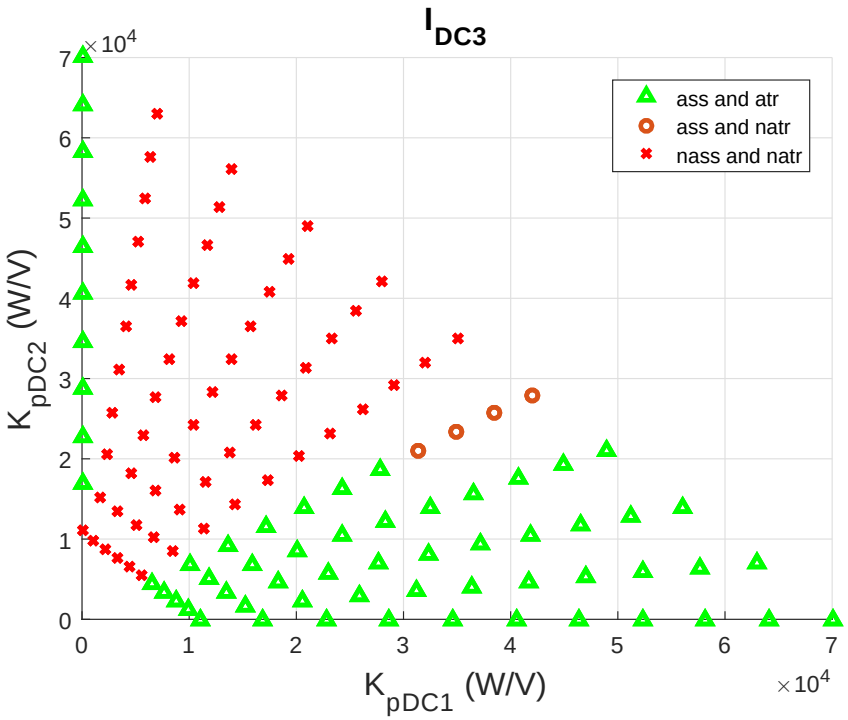

Figure B.48: Admissibility graph of current I_{DC3} from simulation 3 of Case 2

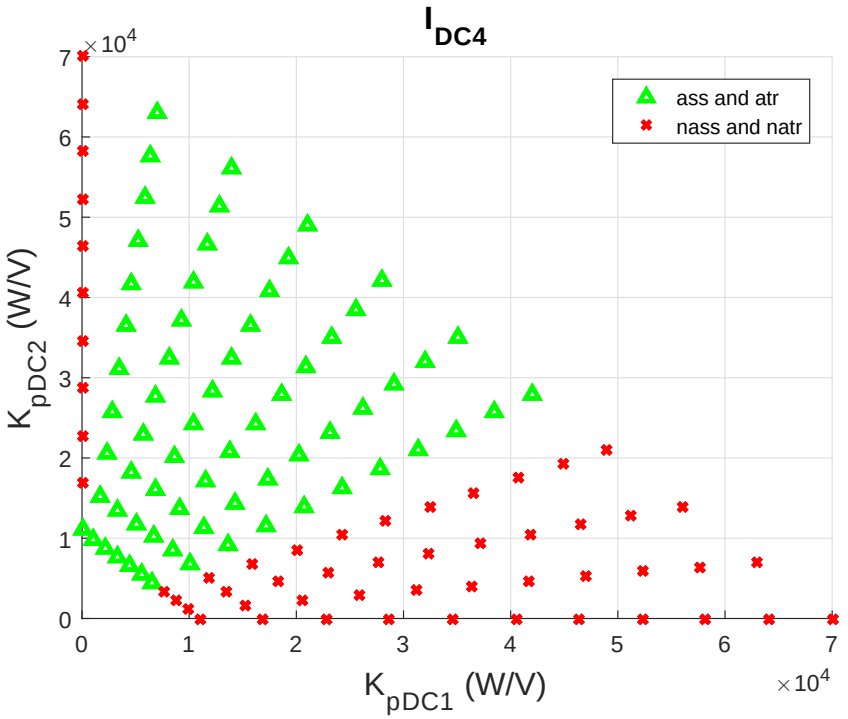

Figure B.49: Admissibility graph of current I_{DC4} from simulation 3 of Case 2

B.3.2 Voltages and currents of power converter 1

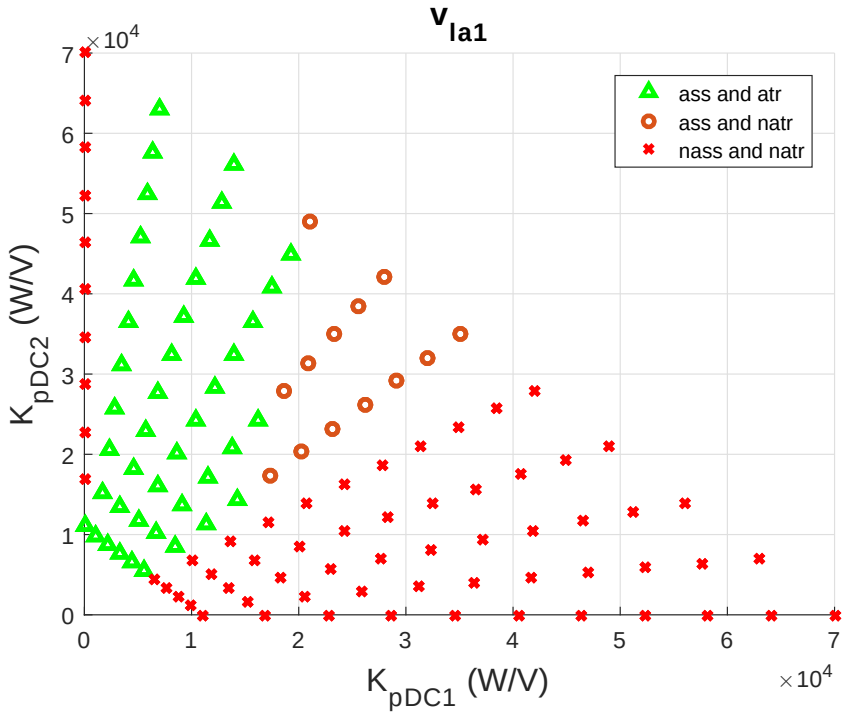

Figure B.50: Admissibility graph of voltage v_{la1} from simulation 3 of Case 2

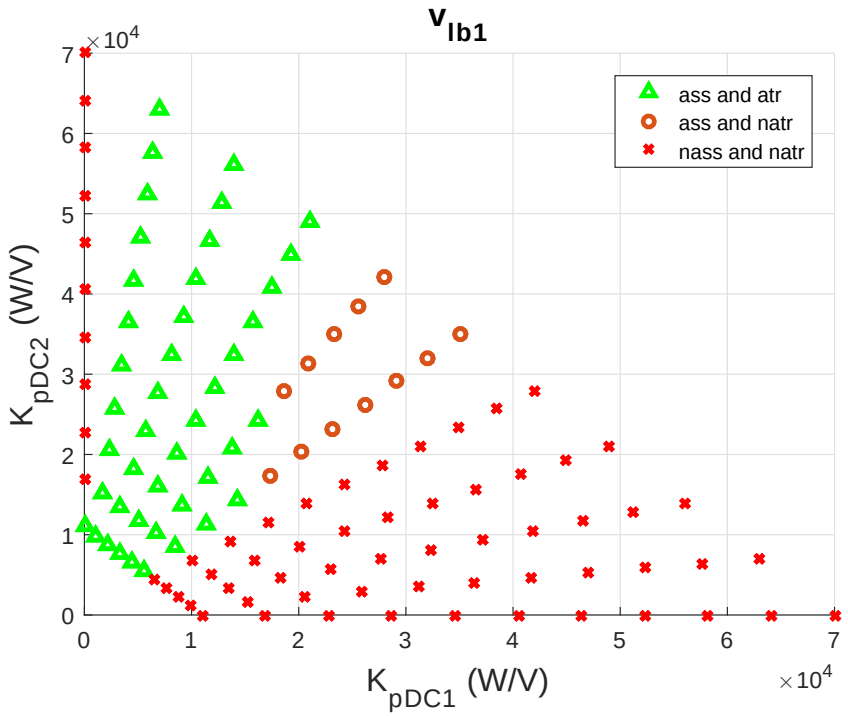

Figure B.51: Admissibility graph of voltage v_{lb1} from simulation 3 of Case 2

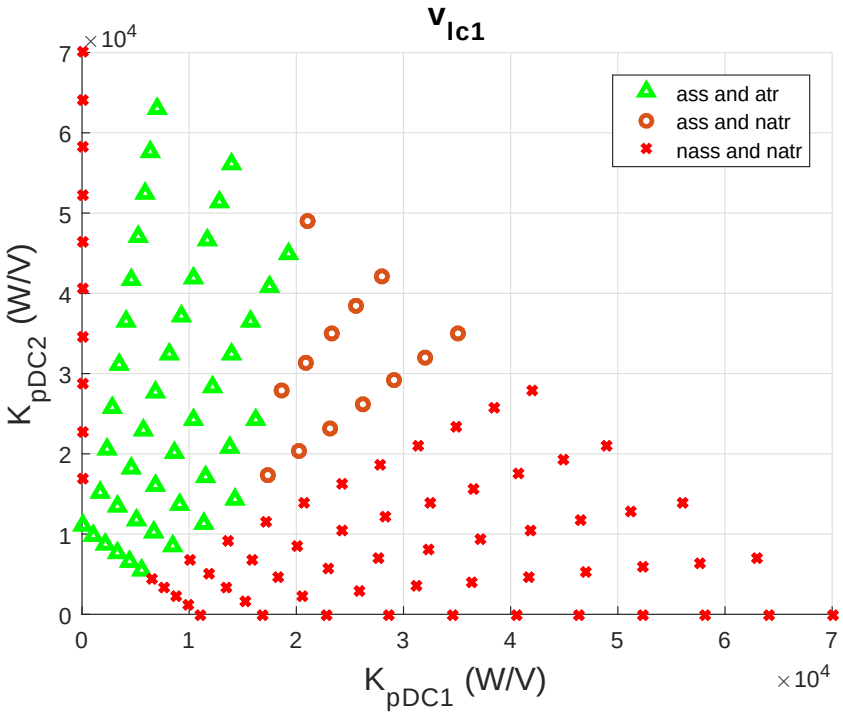

Figure B.52: Admissibility graph of voltage v_{lc1} from simulation 3 of Case 2

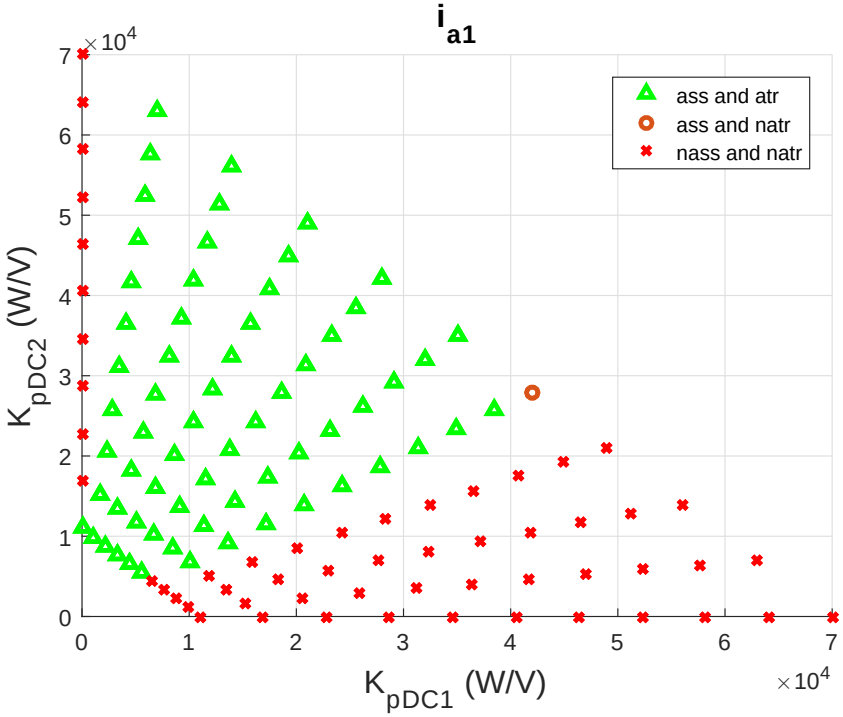

Figure B.53: Admissibility graph of current i_{a1} from simulation 3 of Case 2

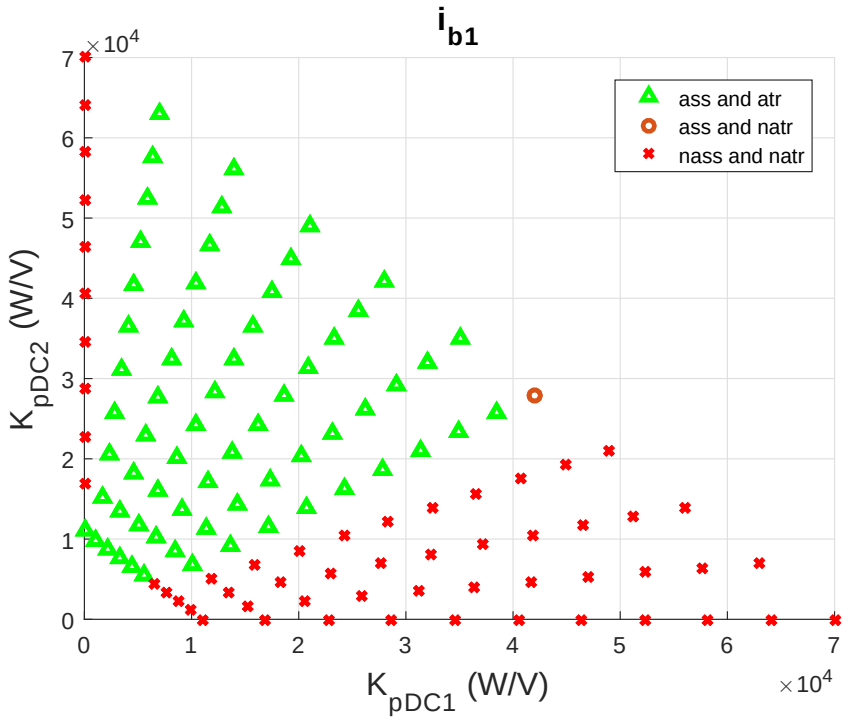

Figure B.54: Admissibility graph of current i_{b1} from simulation 3 of Case 2

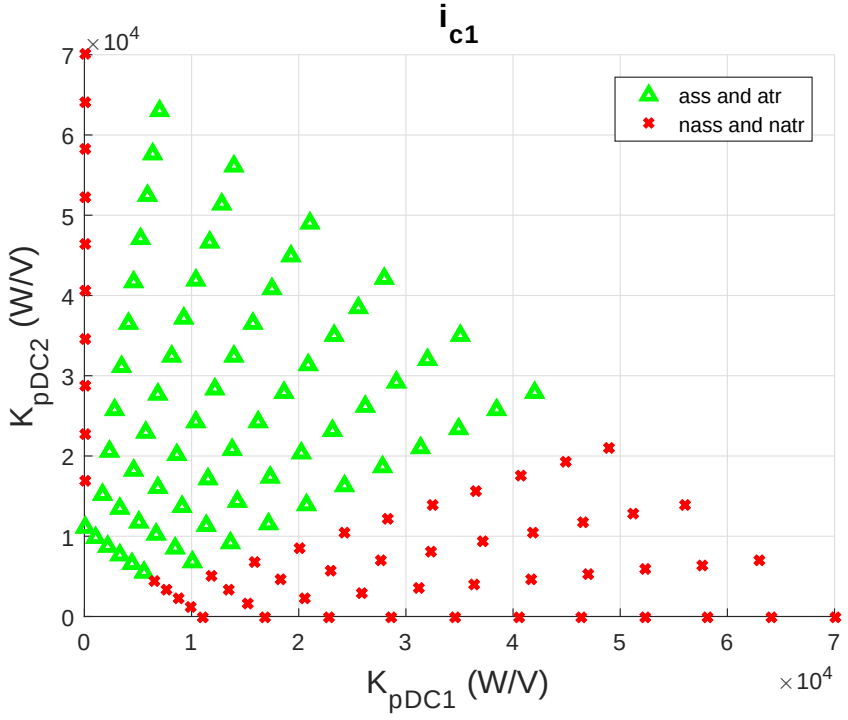

Figure B.55: Admissibility graph of current i_{c1} from simulation 3 of Case 2

B.3.3 Voltages and currents of power converter 2

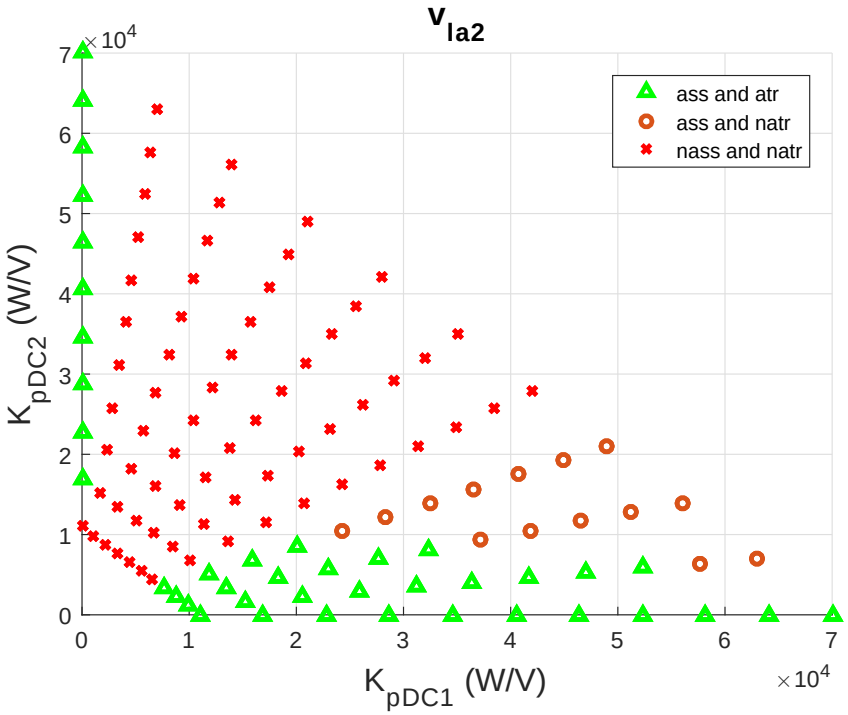

Figure B.56: Admissibility graph of voltage v_{la2} from simulation 3 of Case 2

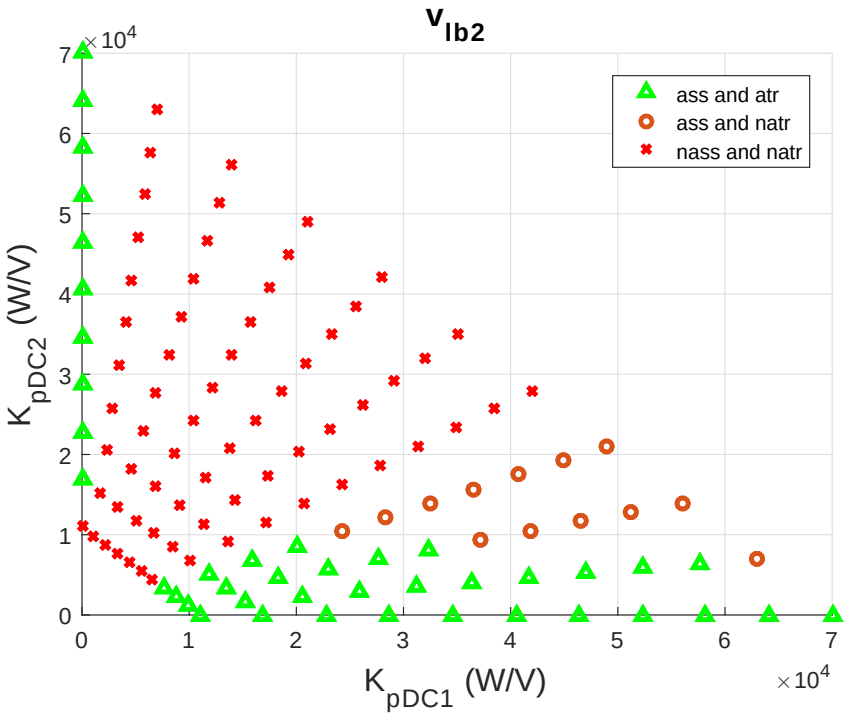

Figure B.57: Admissibility graph of voltage v_{lb2} from simulation 3 of Case 2

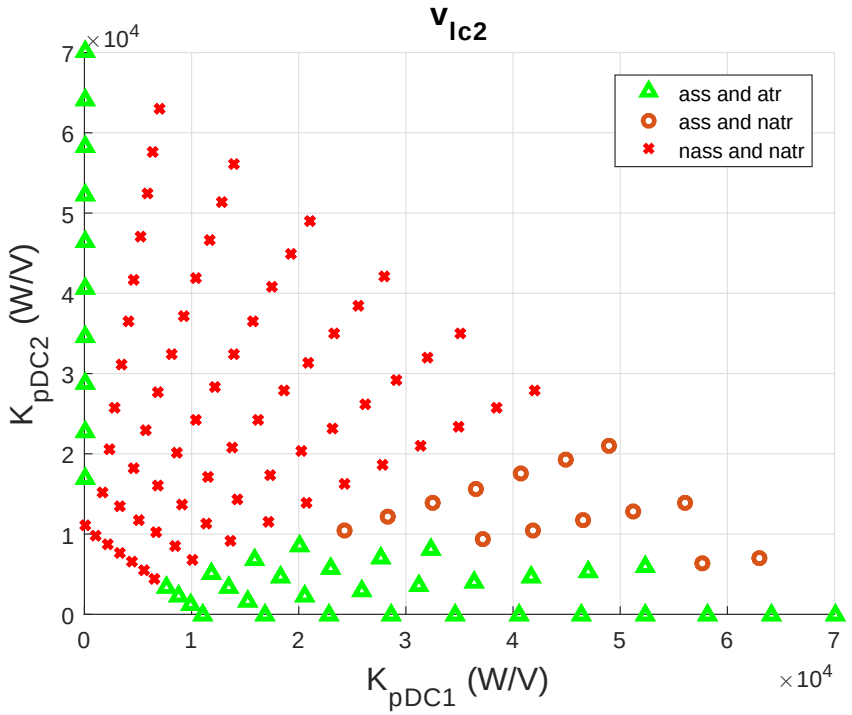

Figure B.58: Admissibility graph of voltage v_{lc2} from simulation 3 of Case 2

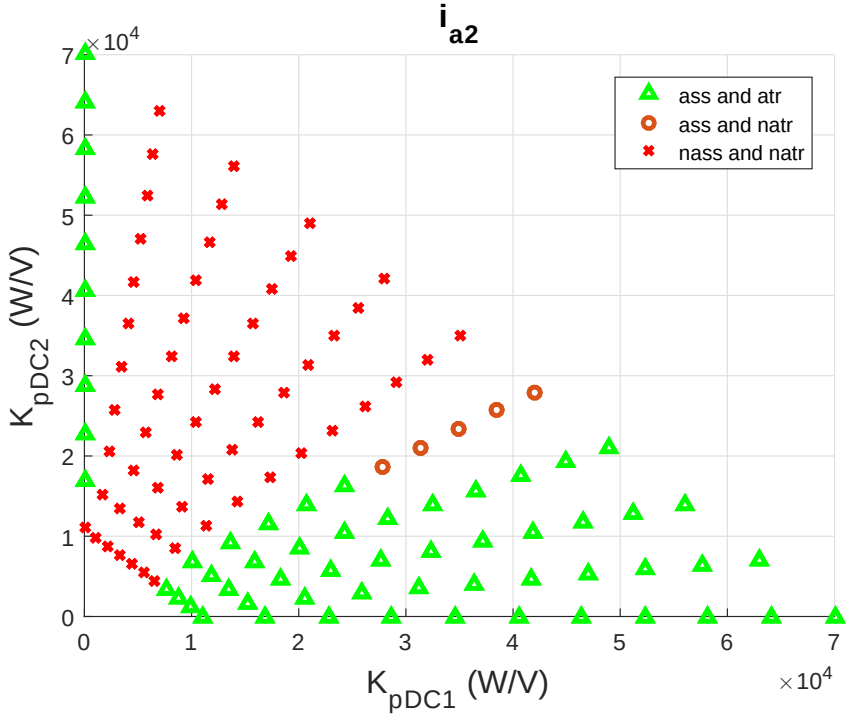

Figure B.59: Admissibility graph of current i_{a2} from simulation 3 of Case 2

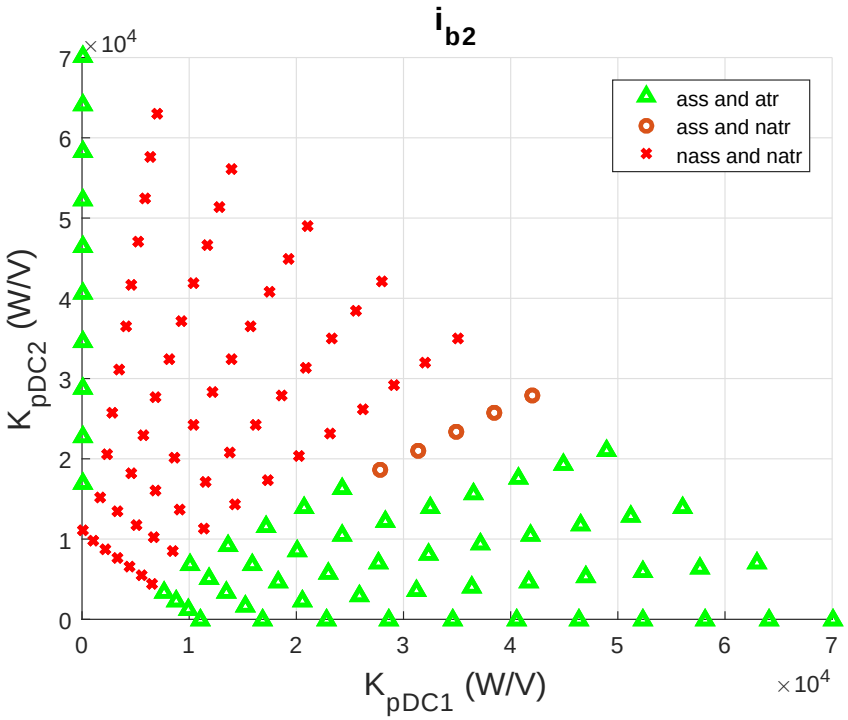

Figure B.60: Admissibility graph of current i_{b2} from simulation 3 of Case 2

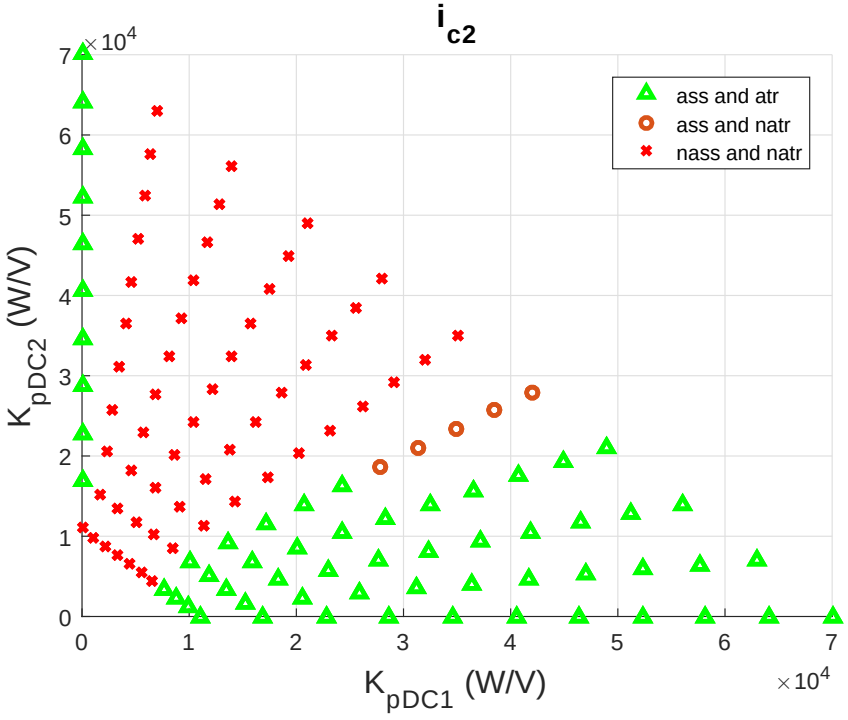

Figure B.61: Admissibility graph of current i_{c2} from simulation 3 of Case 2

B.4 Simulation 4

Simulation 4: $K_{pDC} \in [75000, 150000]$ with a step of 7500. In total 121 simulations for each electrical magnitude.

B.4.1 Voltages and currents of the multi-terminal HVDC grid

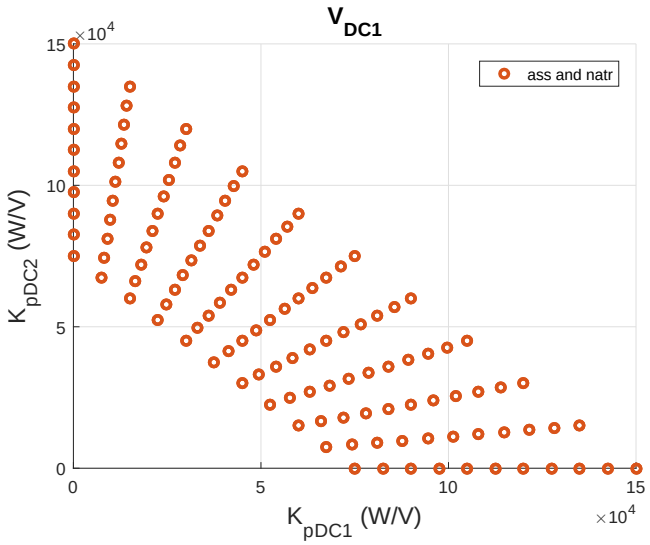

Figure B.62: Admissibility graph of voltage V_{DC1} from simulation 4 of Case 2

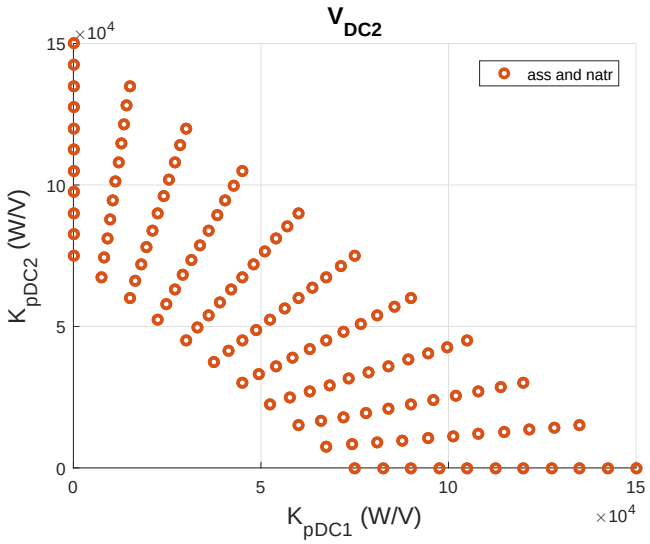

Figure B.63: Admissibility graph of voltage V_{DC2} from simulation 4 of Case 2

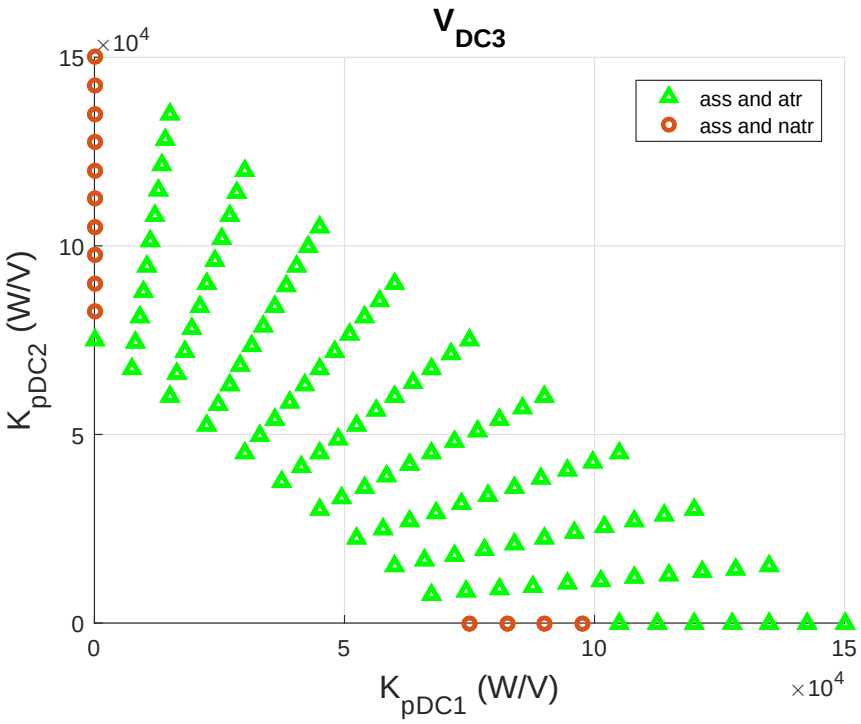

Figure B.64: Admissibility graph of voltage V_{DC3} from simulation 4 of Case 2

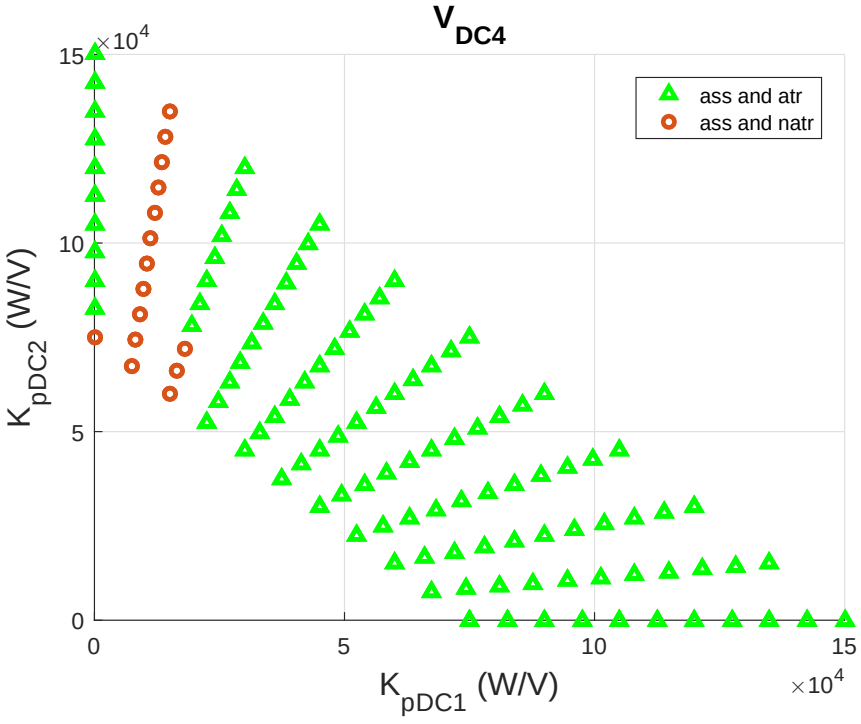

Figure B.65: Admissibility graph of voltage V_{DC4} from simulation 4 of Case 2

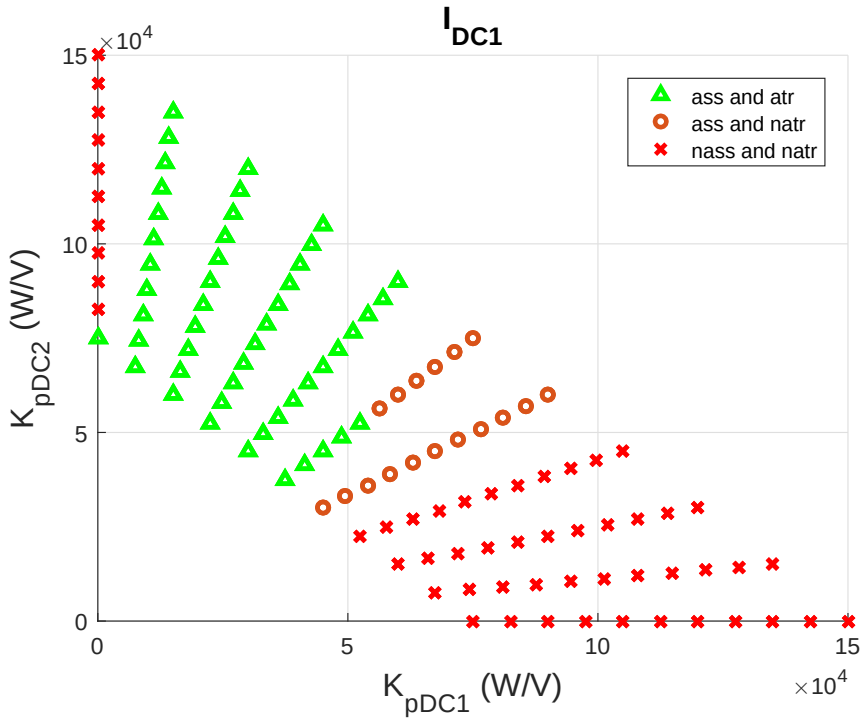

Figure B.66: Admissibility graph of current I_{DC1} from simulation 4 of Case 2

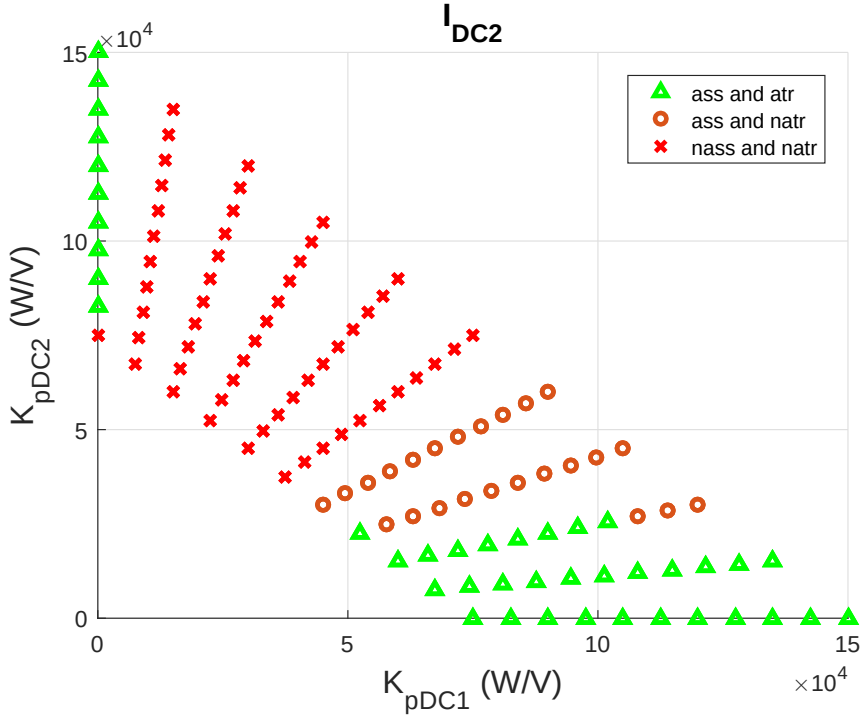

Figure B.67: Admissibility graph of current I_{DC2} from simulation 4 of Case 2

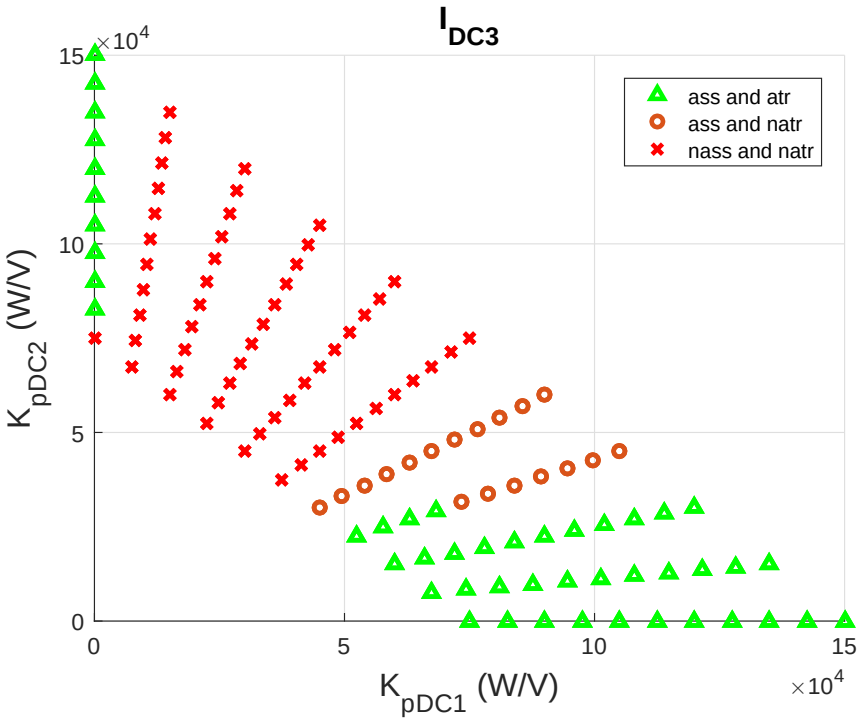

Figure B.68: Admissibility graph of current I_{DC3} from simulation 4 of Case 2

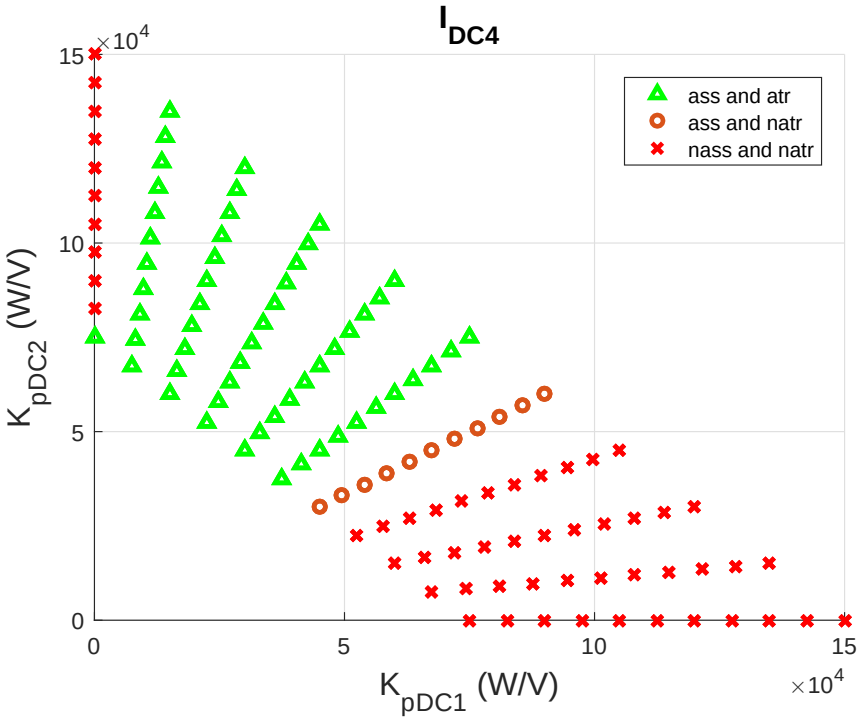

Figure B.69: Admissibility graph of current I_{DC4} from simulation 4 of Case 2

B.4.2 Voltages and currents of power converter 1

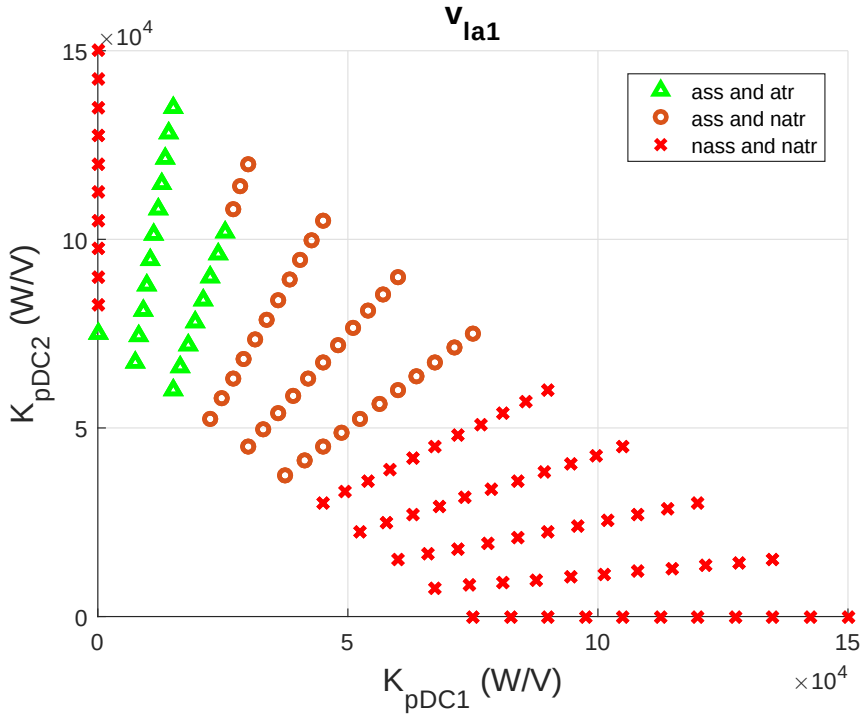

Figure B.70: Admissibility graph of voltage v_{la1} from simulation 4 of Case 2

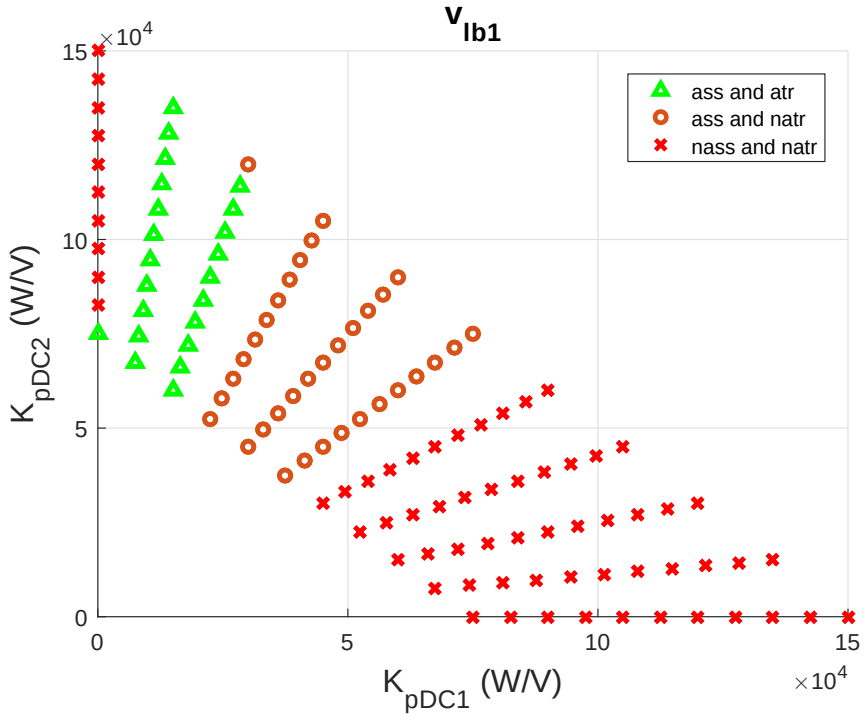

Figure B.71: Admissibility graph of voltage v_{lb1} from simulation 4 of Case 2

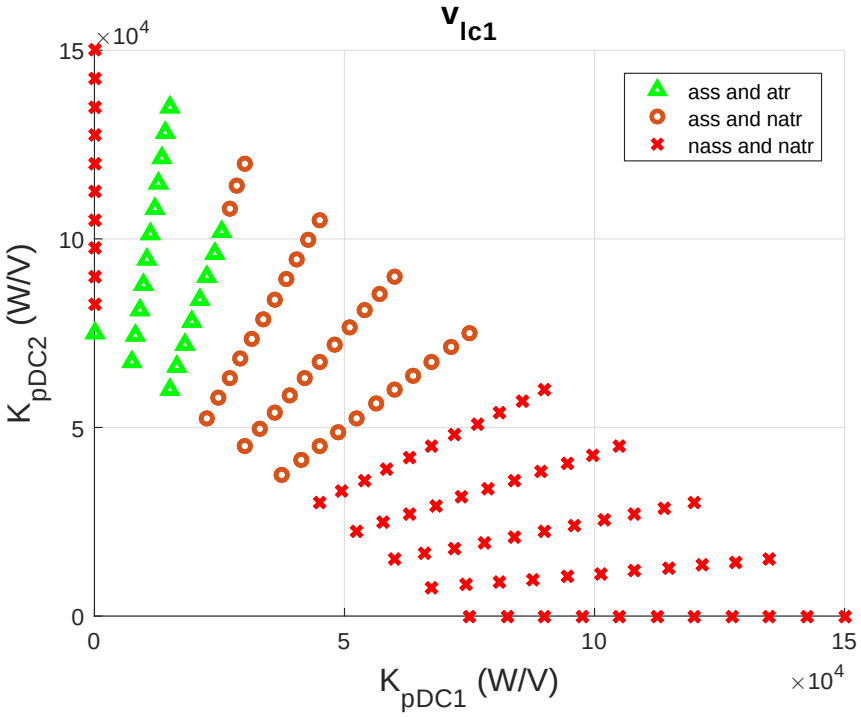

Figure B.72: Admissibility graph of voltage v_{lc1} from simulation 4 of Case 2

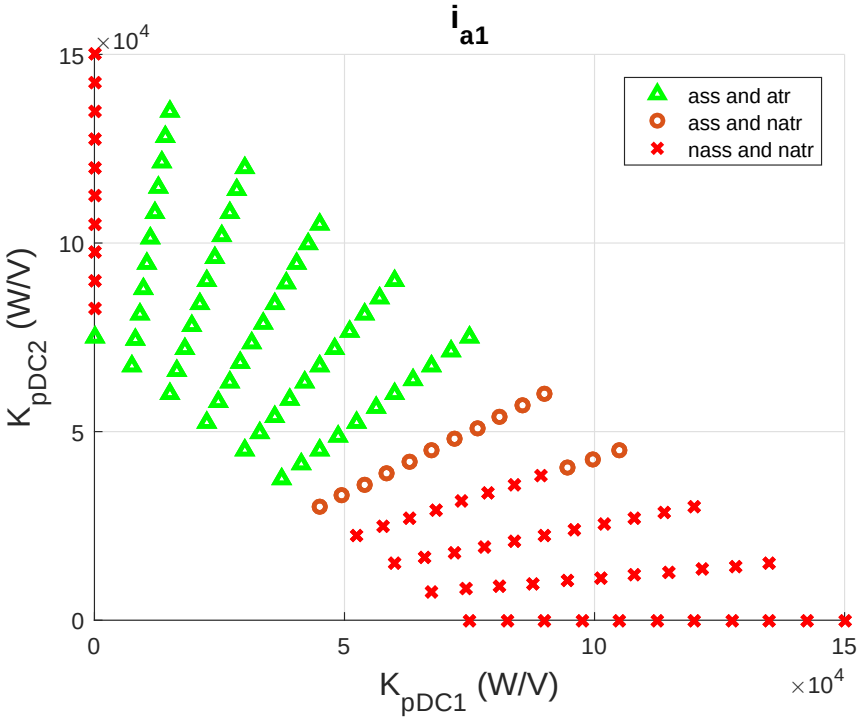

Figure B.73: Admissibility graph of current i_{a1} from simulation 4 of Case 2

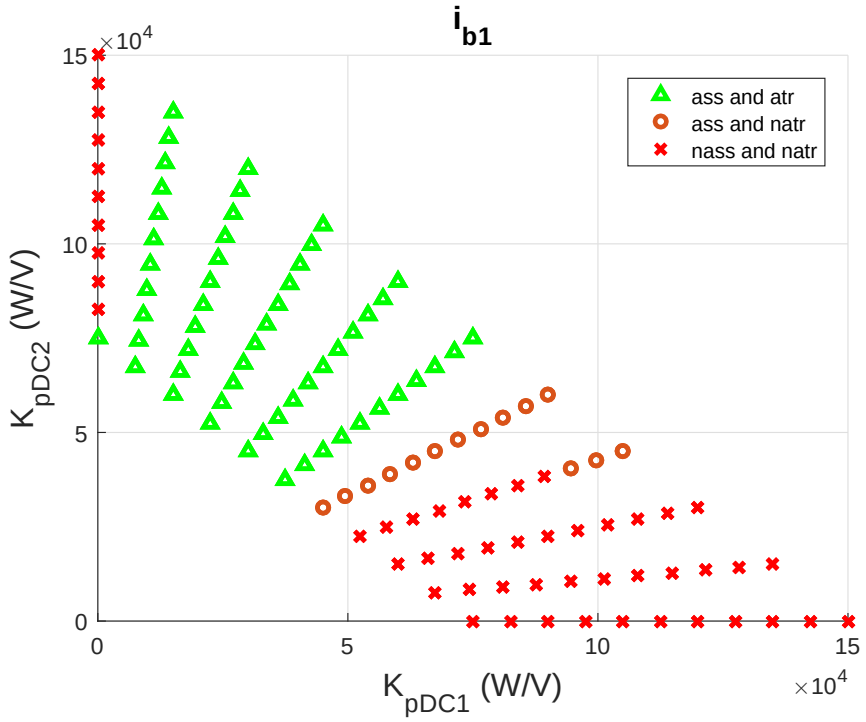

Figure B.74: Admissibility graph of current i_{b1} from simulation 4 of Case 2

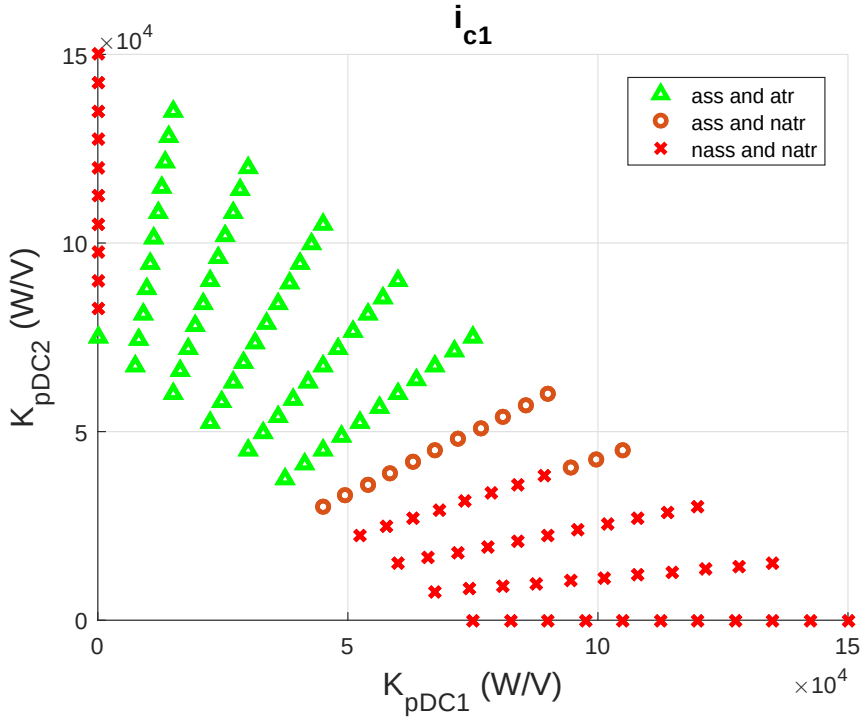

Figure B.75: Admissibility graph of current i_{c1} from simulation 4 of Case 2

B.4.3 Voltages and currents of power converter 2

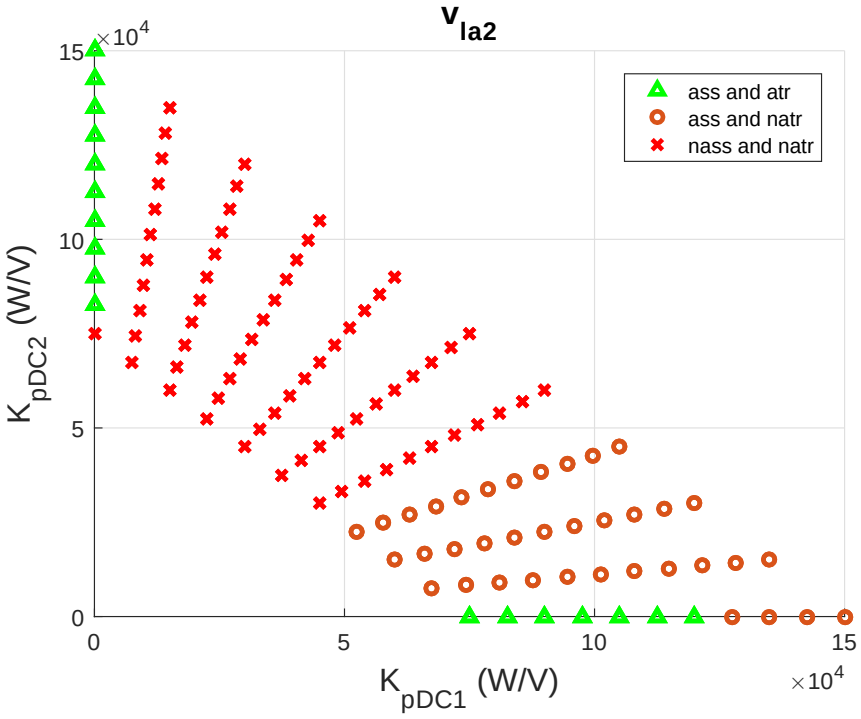

Figure B.76: Admissibility graph of voltage v_{la2} from simulation 4 of Case 2

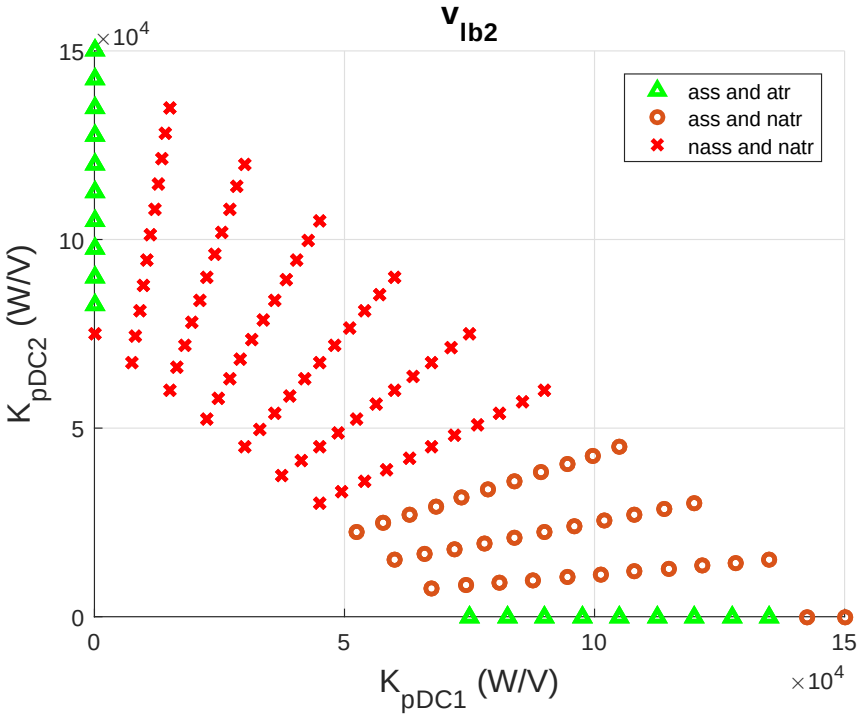

Figure B.77: Admissibility graph of voltage v_{lb2} from simulation 4 of Case 2

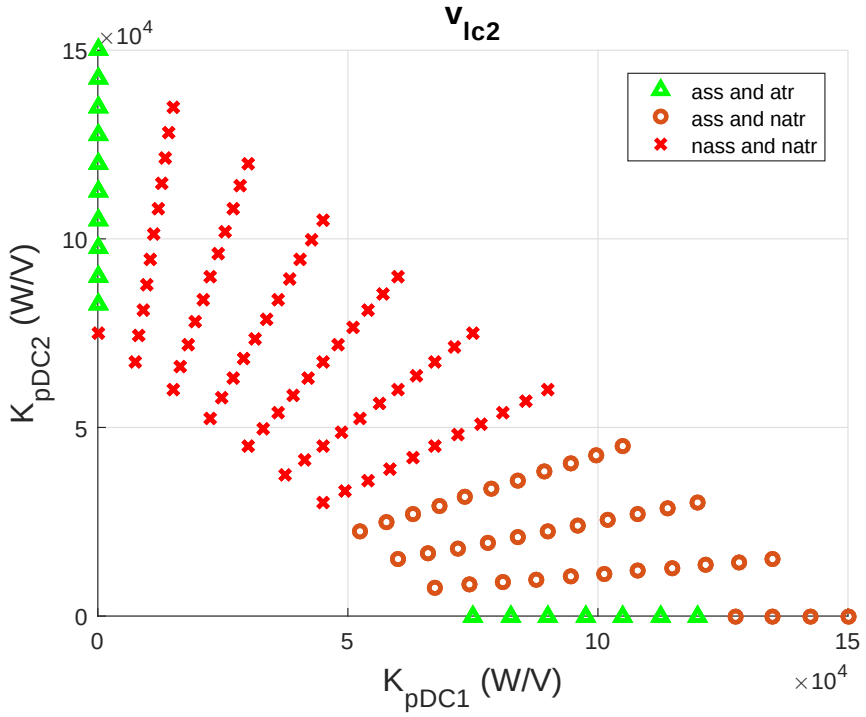

Figure B.78: Admissibility graph of voltage v_{lc2} from simulation 4 of Case 2

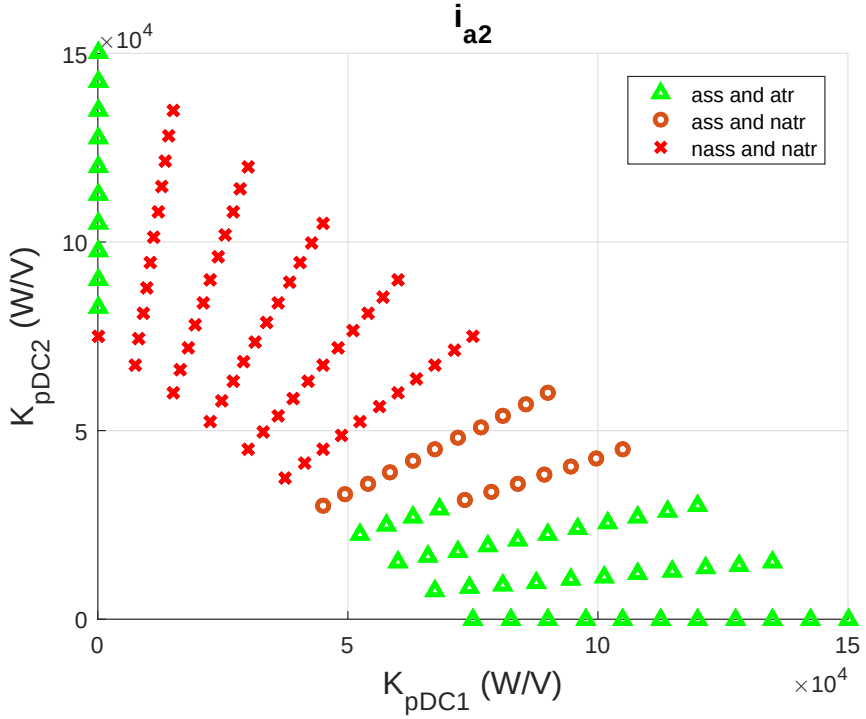

Figure B.79: Admissibility graph of current i_{a2} from simulation 4 of Case 2

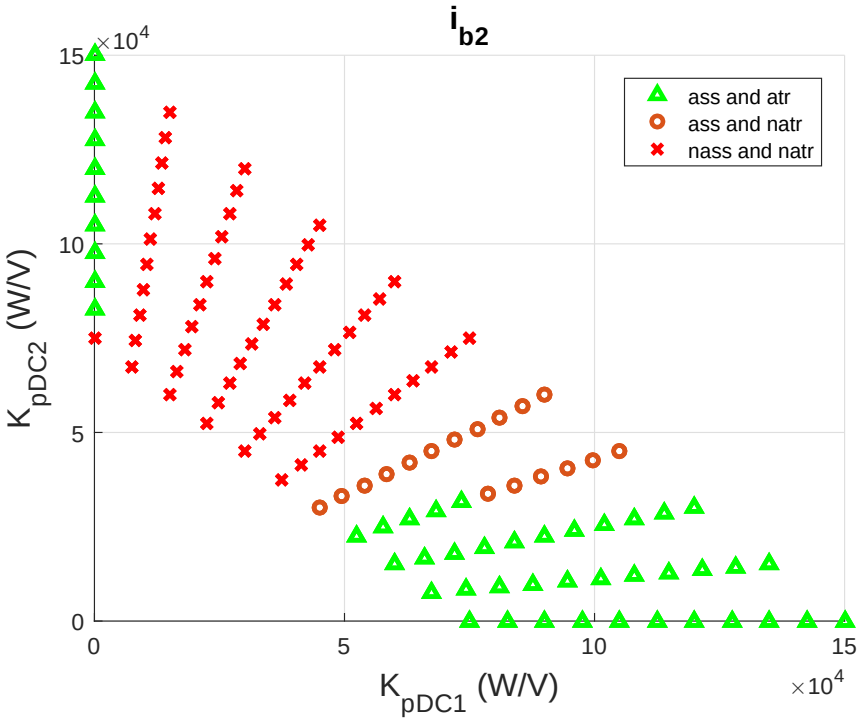

Figure B.80: Admissibility graph of current i_{b2} from simulation 4 of Case 2

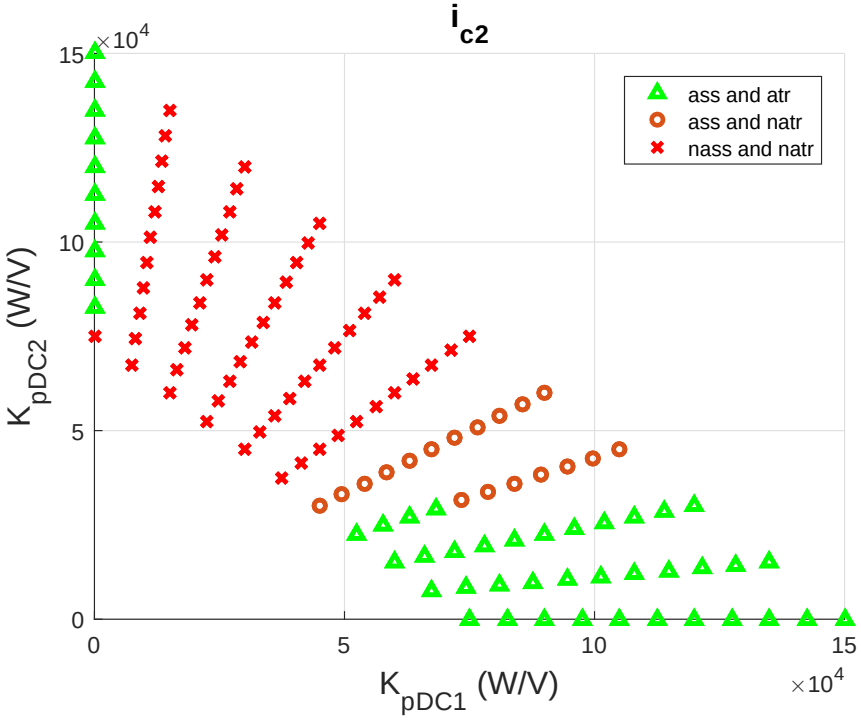

Figure B.81: Admissibility graph of current i_{c2} from simulation 4 of Case 2

B.5 Simulation 5

Simulation 5: $K_{pDC} \in [200, 1800]$ with a step of 200. In total 99 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.5.1 Voltages and currents of the multi-terminal HVDC grid

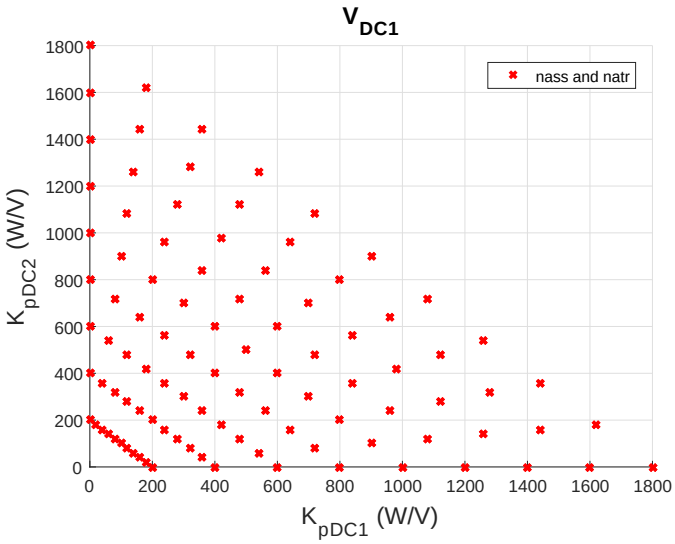

Figure B.82: Admissibility graph of voltage V_{DC1} from simulation 5 of Case 2

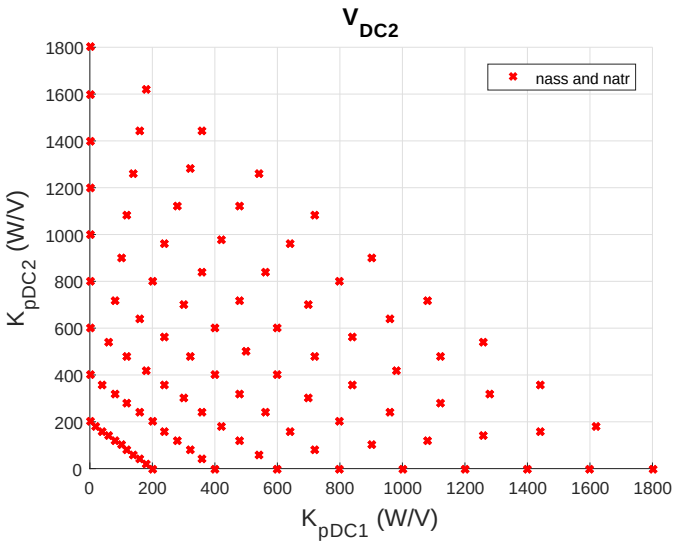

Figure B.83: Admissibility graph of voltage V_{DC2} from simulation 5 of Case 2

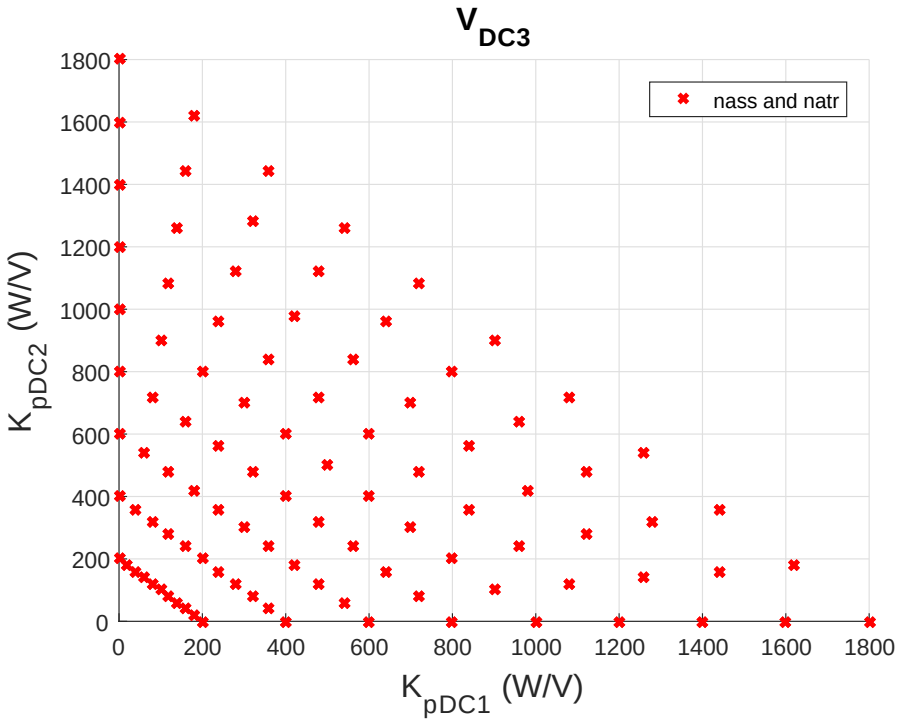

Figure B.84: Admissibility graph of voltage V_{DC3} from simulation 5 of Case 2

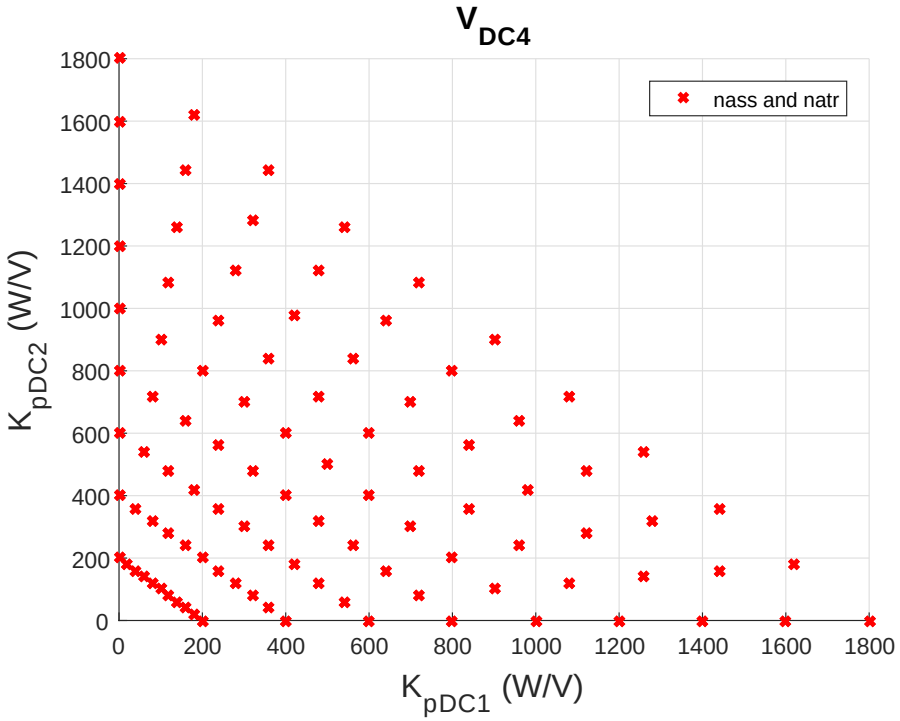

Figure B.85: Admissibility graph of voltage V_{DC4} from simulation 5 of Case 2

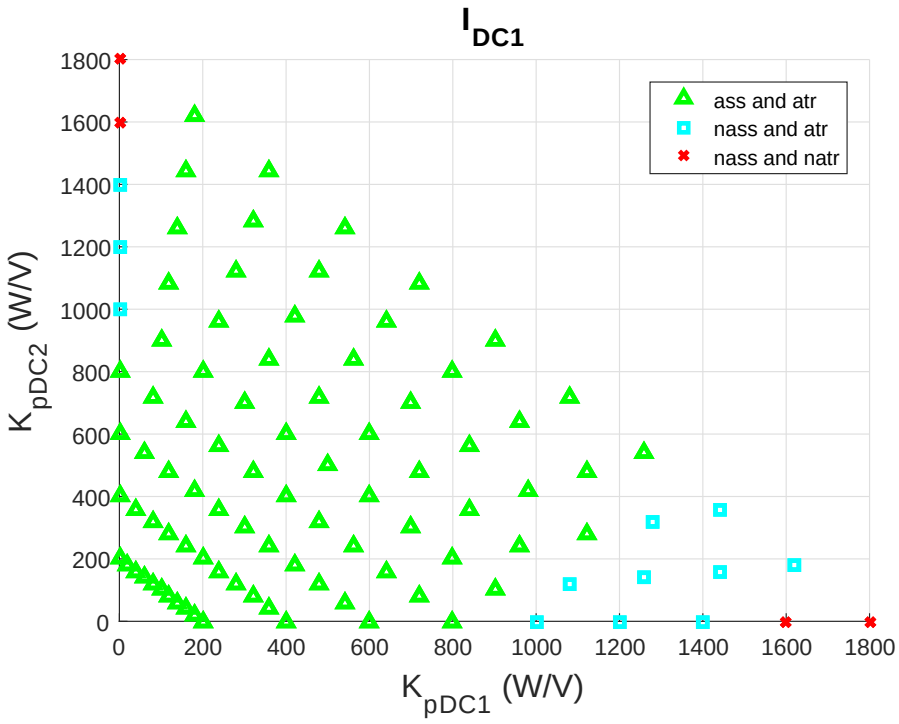

Figure B.86: Admissibility graph of current I_{DC1} from simulation 5 of Case 2

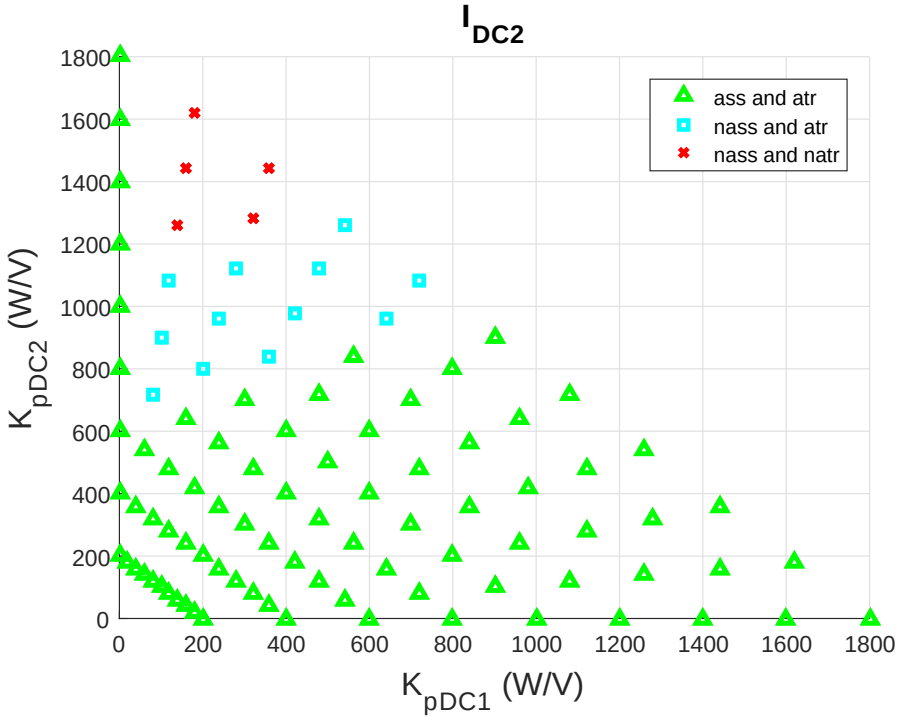

Figure B.87: Admissibility graph of current I_{DC2} from simulation 5 of Case 2

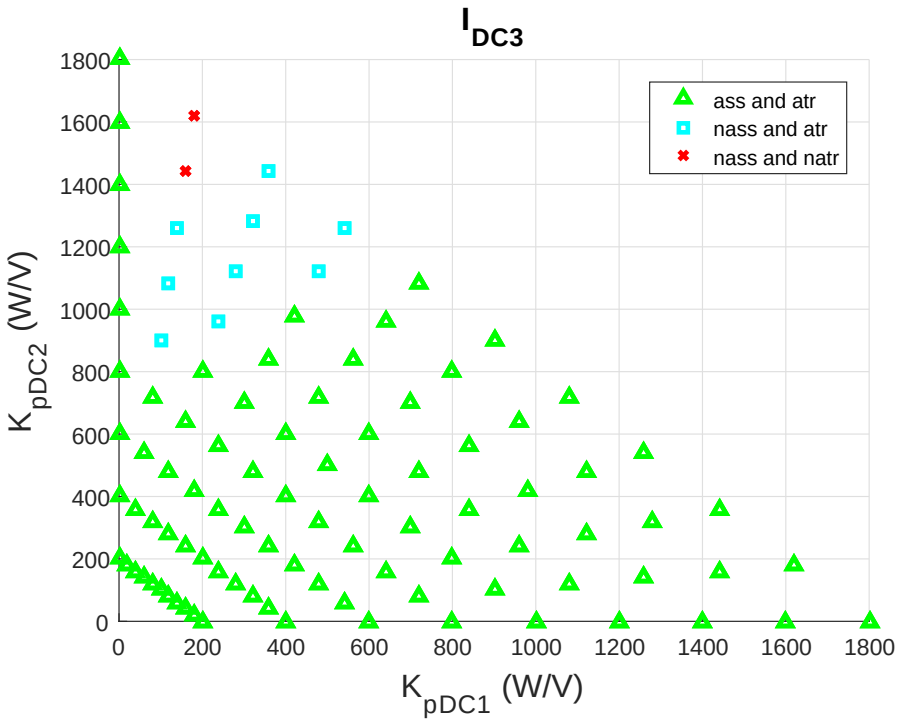

Figure B.88: Admissibility graph of current I_{DC3} from simulation 5 of Case 2

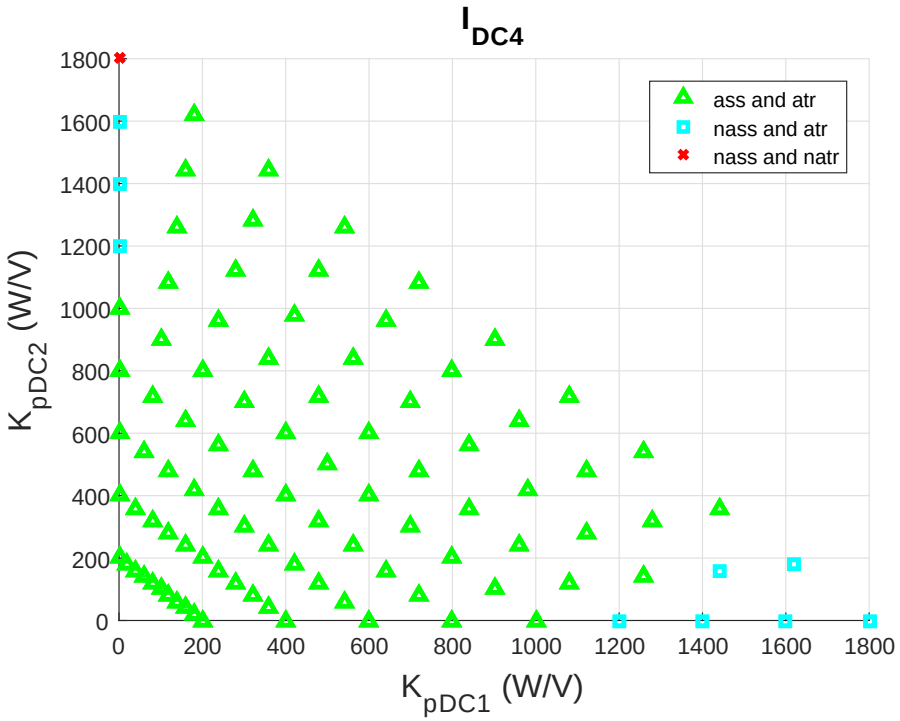

Figure B.89: Admissibility graph of current I_{DC4} from simulation 5 of Case 2

B.5.2 Voltages and currents of power converter 1

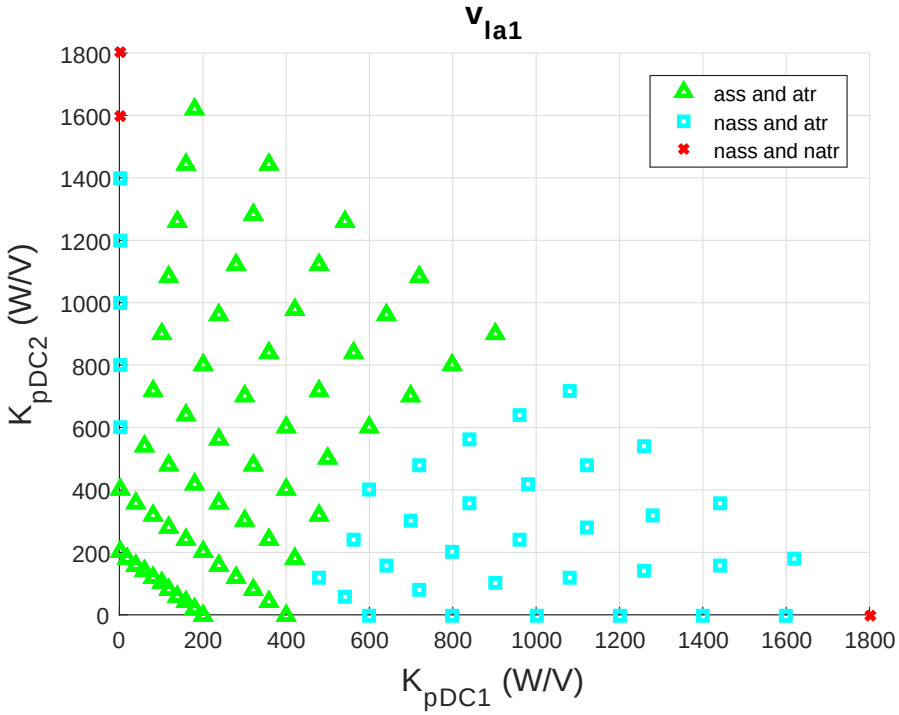

Figure B.90: Admissibility graph of voltage v_{la1} from simulation 5 of Case 2

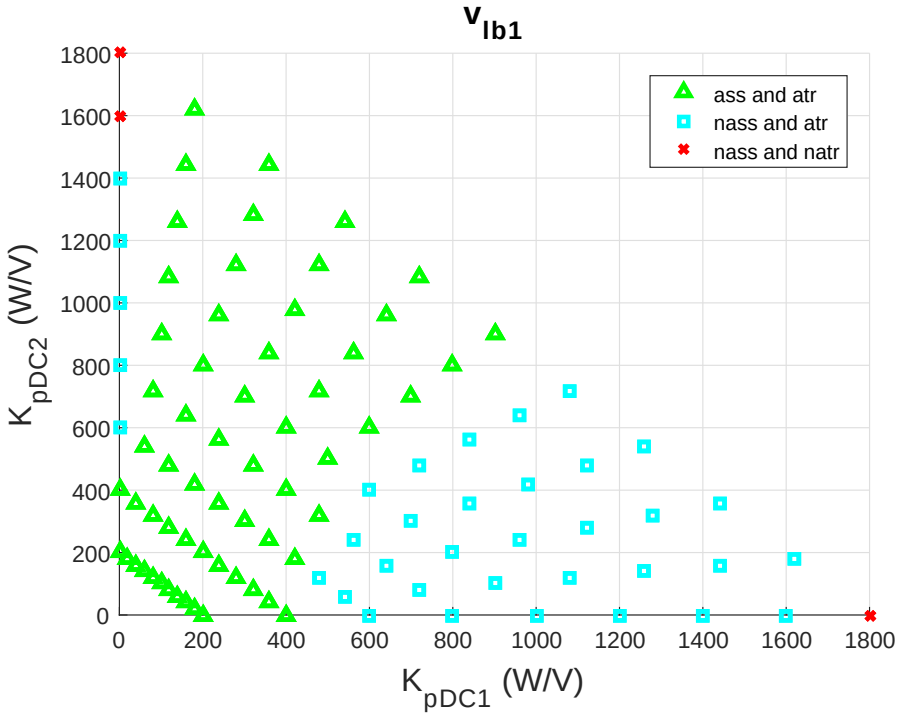

Figure B.91: Admissibility graph of voltage v_{lb1} from simulation 5 of Case 2

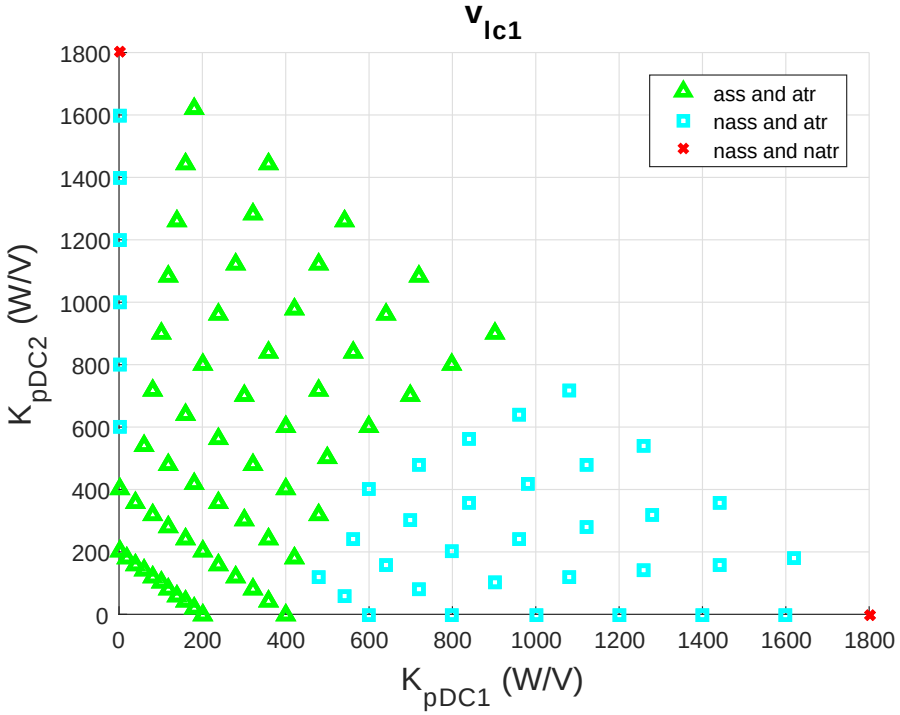

Figure B.92: Admissibility graph of voltage v_{lc1} from simulation 5 of Case 2

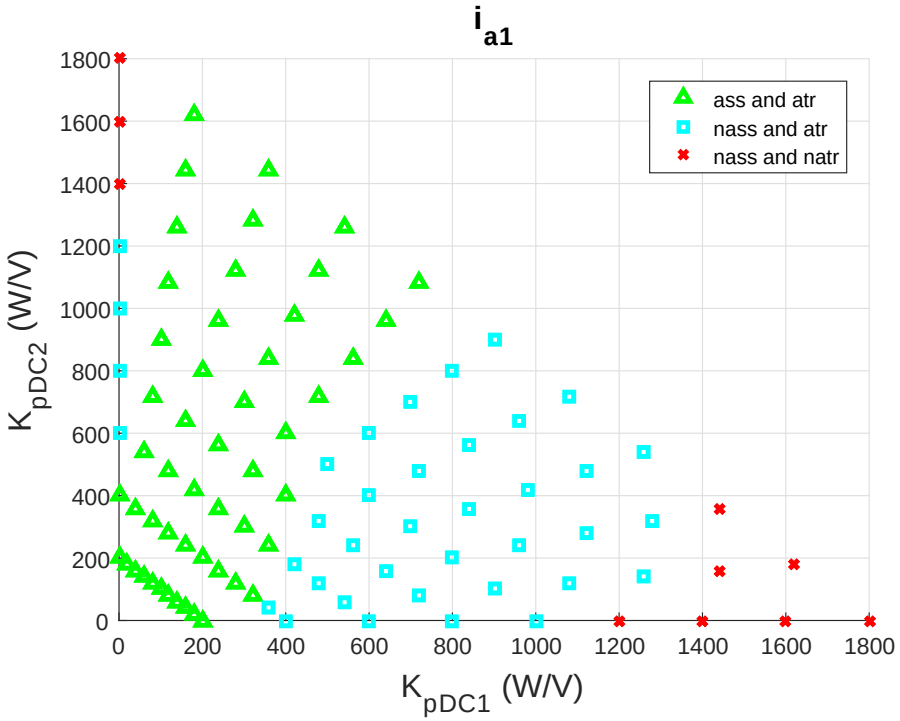

Figure B.93: Admissibility graph of current i_{a1} from simulation 5 of Case 2

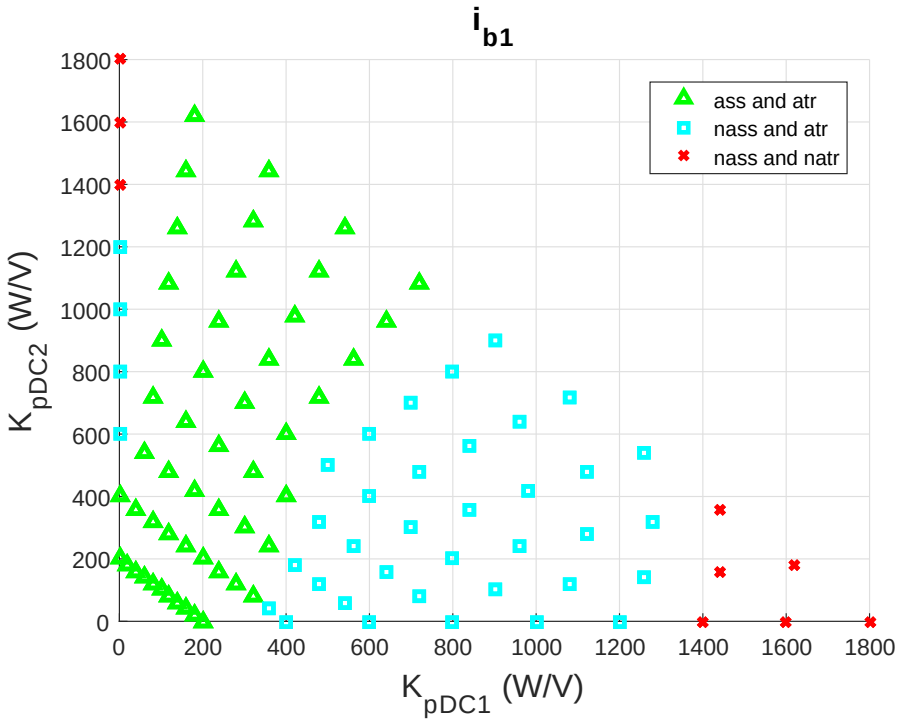

Figure B.94: Admissibility graph of current i_{b1} from simulation 5 of Case 2

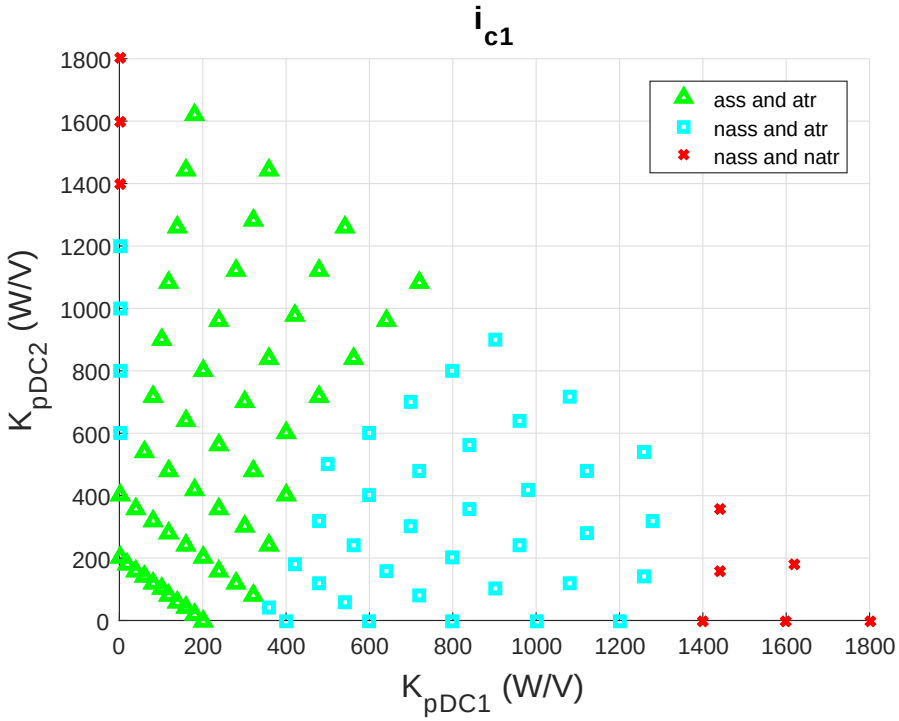

Figure B.95: Admissibility graph of current i_{c1} from simulation 5 of Case 2

B.5.3 Voltages and currents of power converter 2

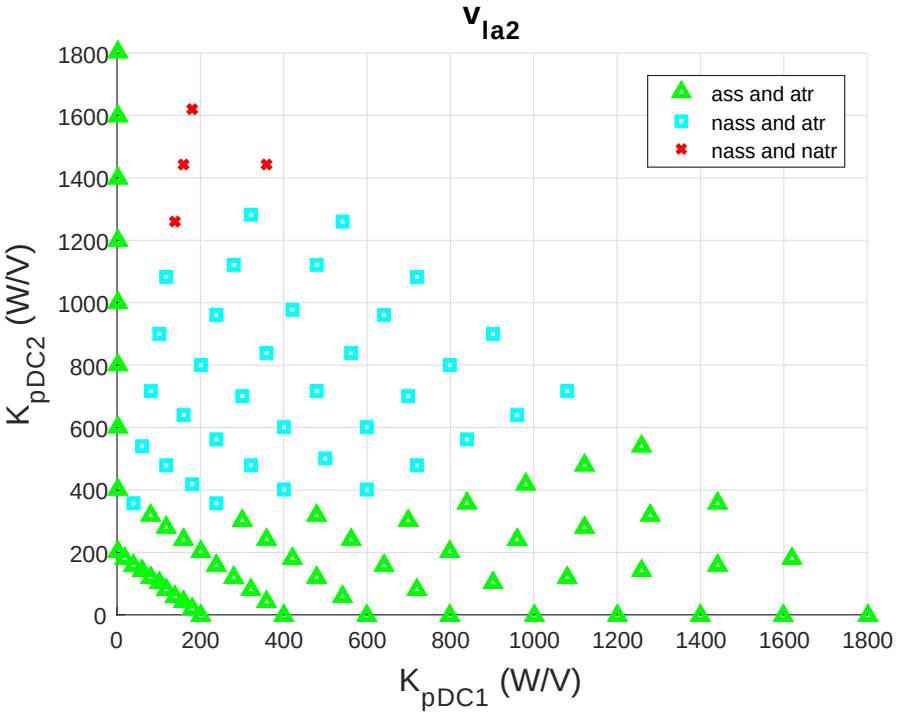

Figure B.96: Admissibility graph of voltage v_{la2} from simulation 5 of Case 2

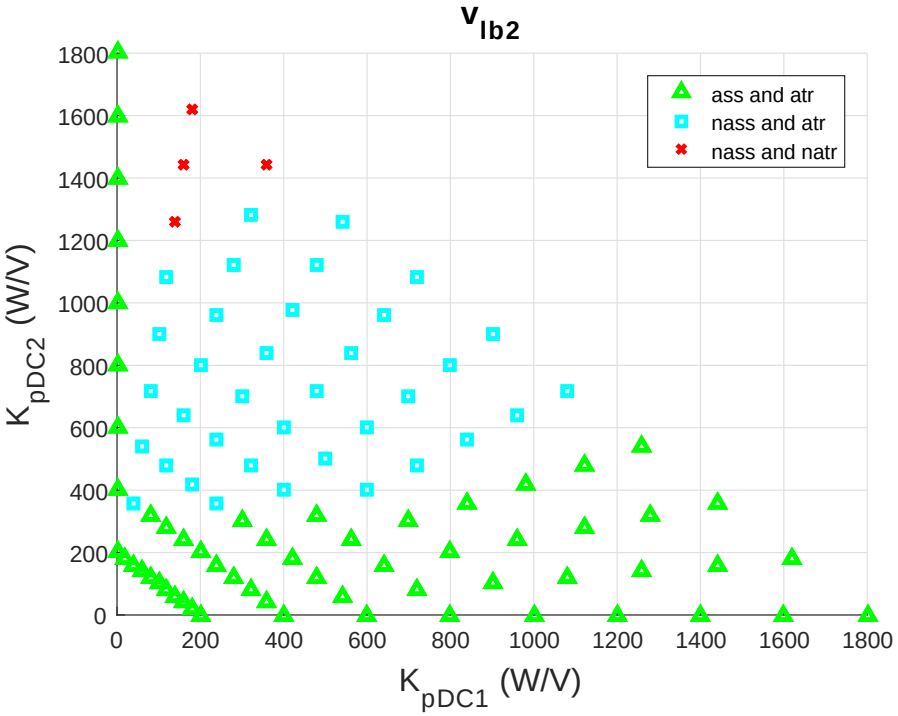

Figure B.97: Admissibility graph of voltage v_{lb2} from simulation 5 of Case 2

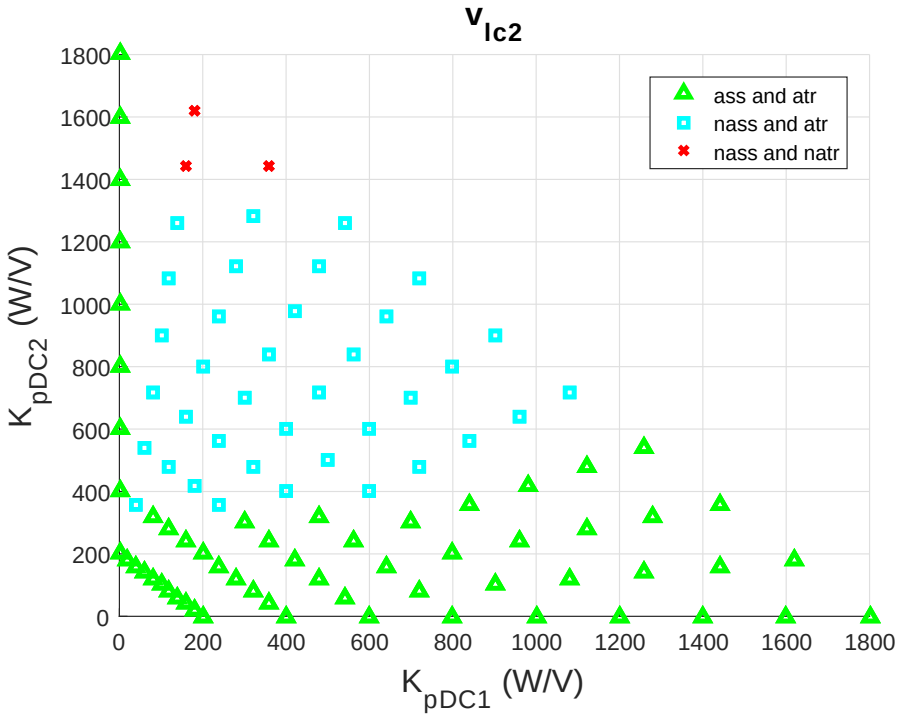

Figure B.98: Admissibility graph of voltage v_{lc2} from simulation 5 of Case 2

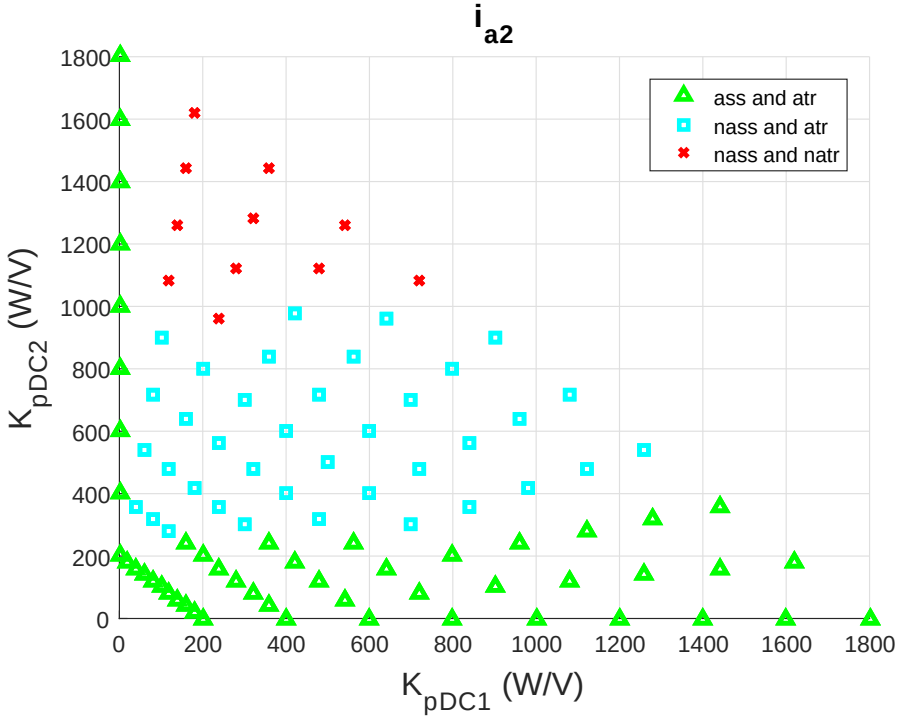

Figure B.99: Admissibility graph of current i_{a2} from simulation 5 of Case 2

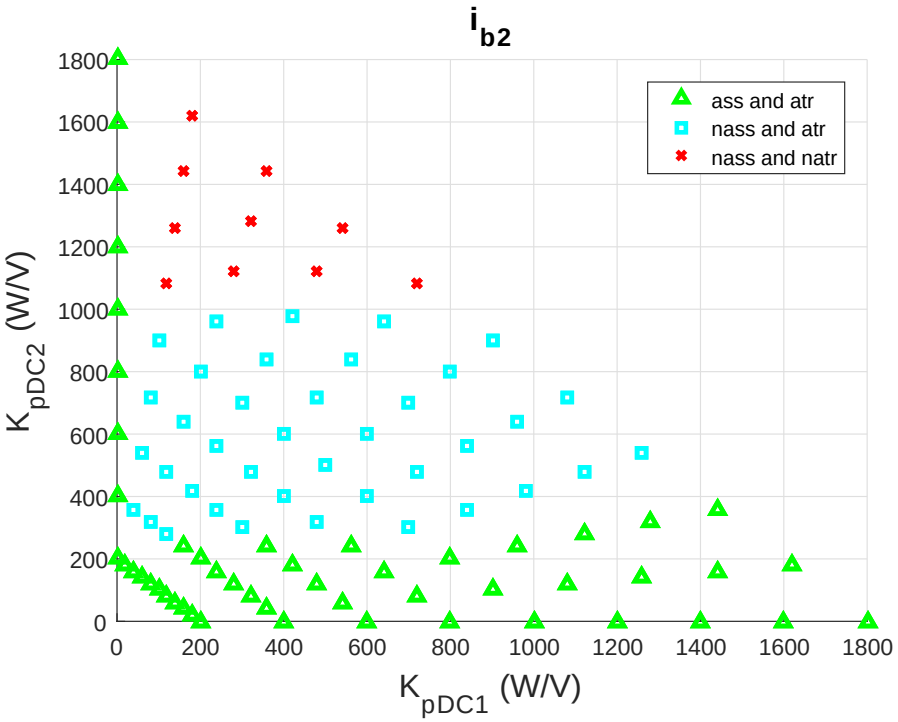

Figure B.100: Admissibility graph of current i_{b2} from simulation 5 of Case 2

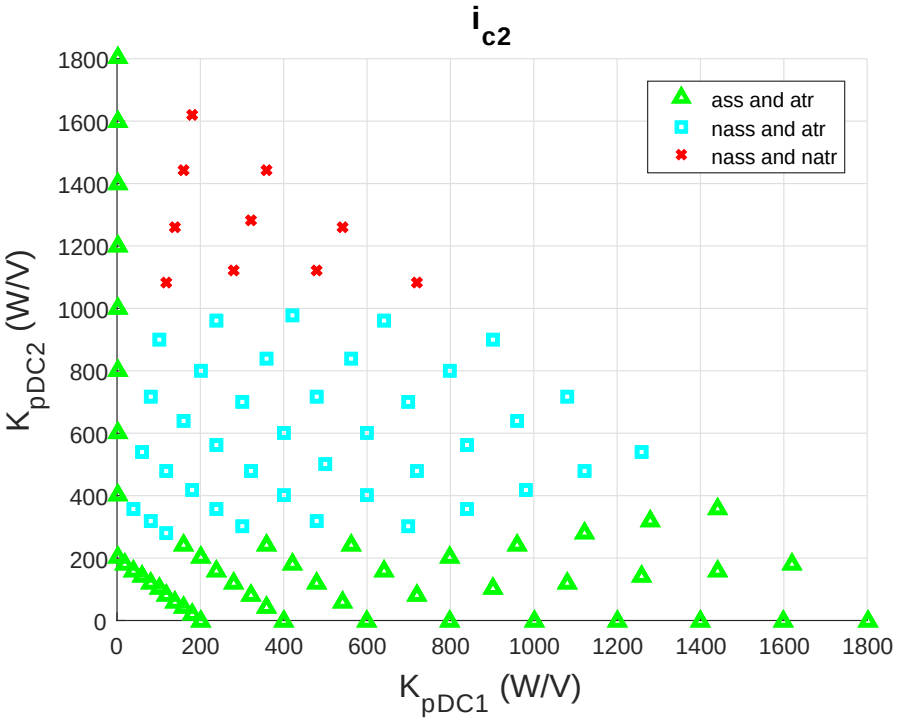

Figure B.101: Admissibility graph of current i_{c2} from simulation 5 of Case 2

B.6 Simulation 6

Simulation 6: $K_{pDC} \in [2000, 10000]$ with a step of 1000. In total 99 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.6.1 Voltages and currents of the multi-terminal HVDC grid

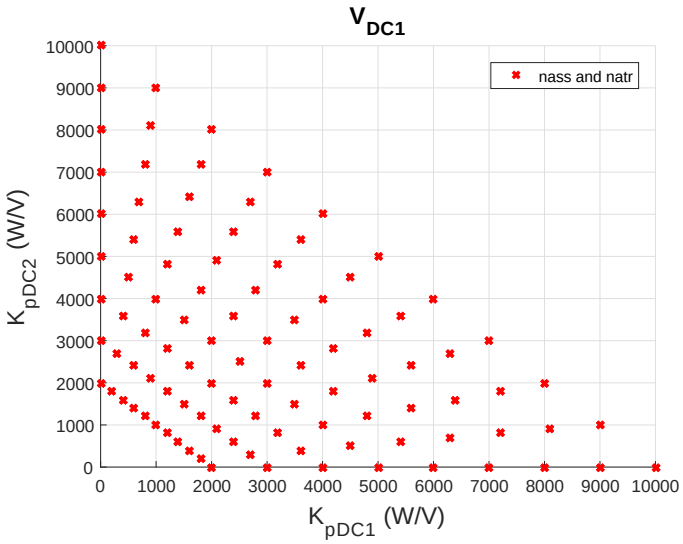

Figure B.102: Admissibility graph of voltage V_{DC1} from simulation 6 of Case 2

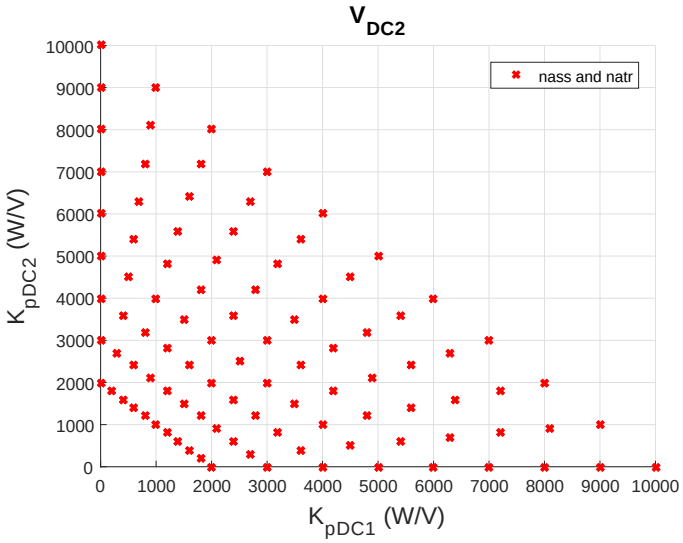

Figure B.103: Admissibility graph of voltage V_{DC2} from simulation 6 of Case 2

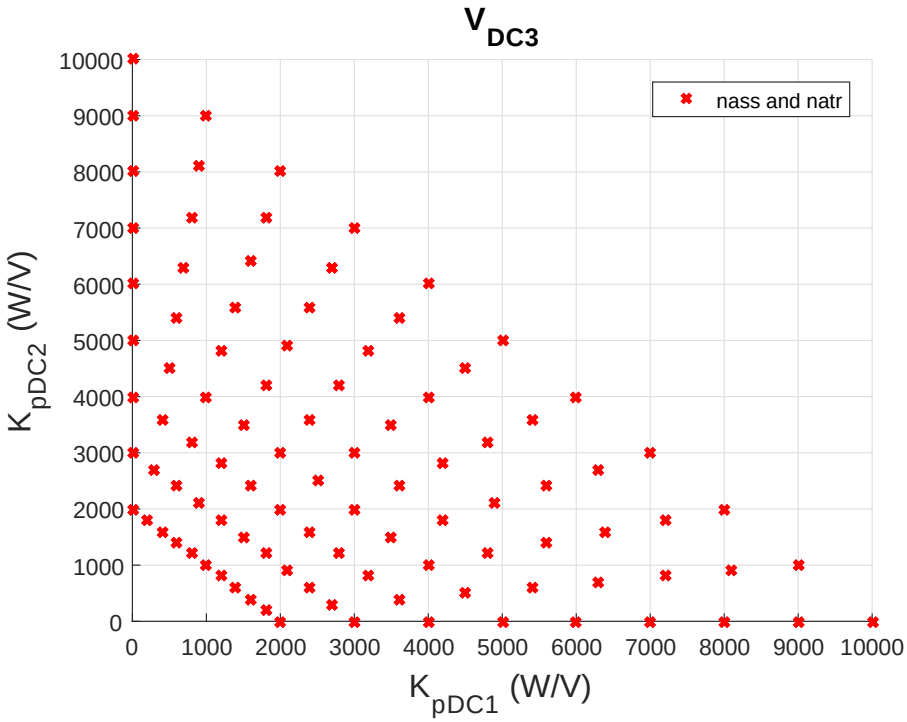

Figure B.104: Admissibility graph of voltage V_{DC3} from simulation 6 of Case 2

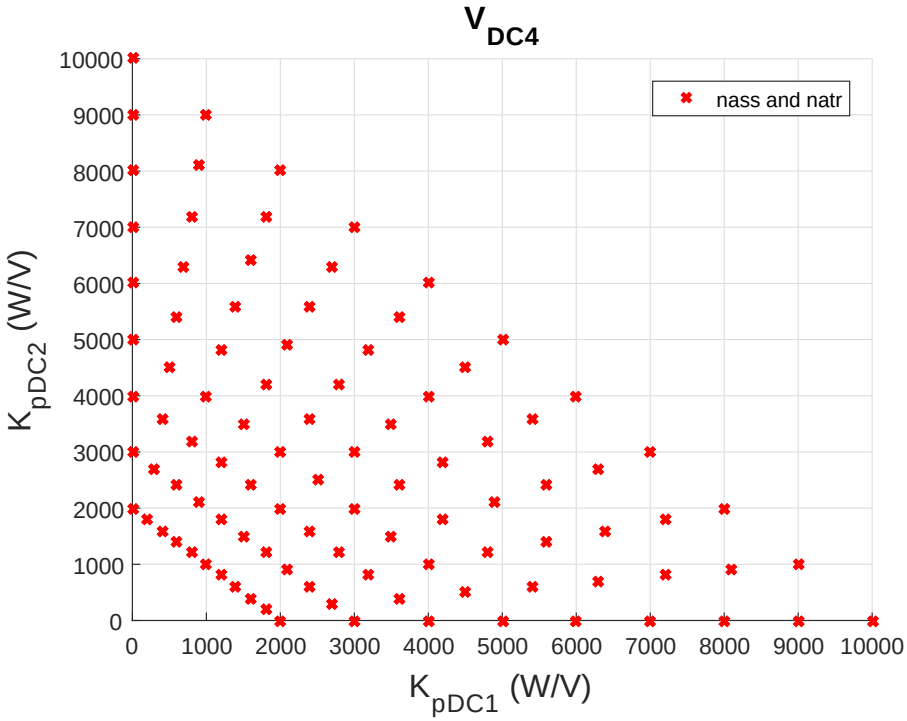

Figure B.105: Admissibility graph of voltage V_{DC4} from simulation 6 of Case 2

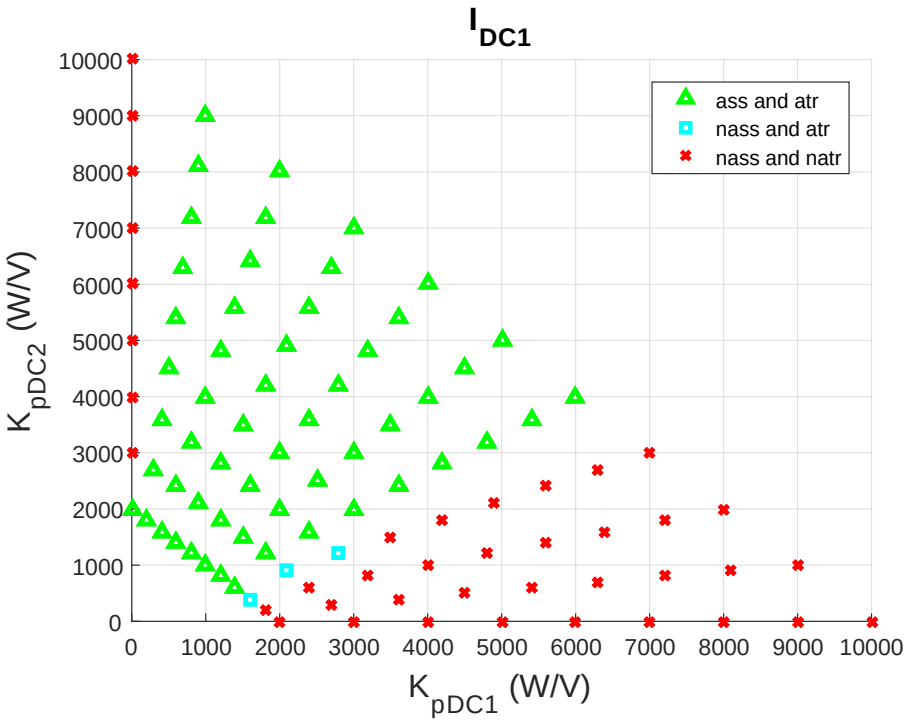

Figure B.106: Admissibility graph of current I_{DC1} from simulation 6 of Case 2

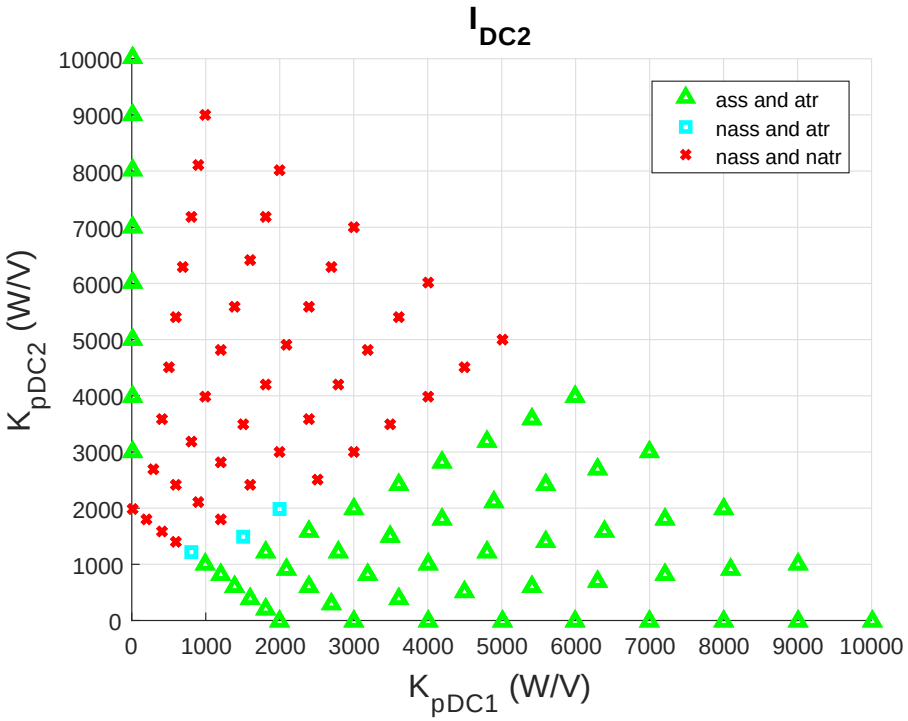

Figure B.107: Admissibility graph of current I_{DC2} from simulation 6 of Case 2

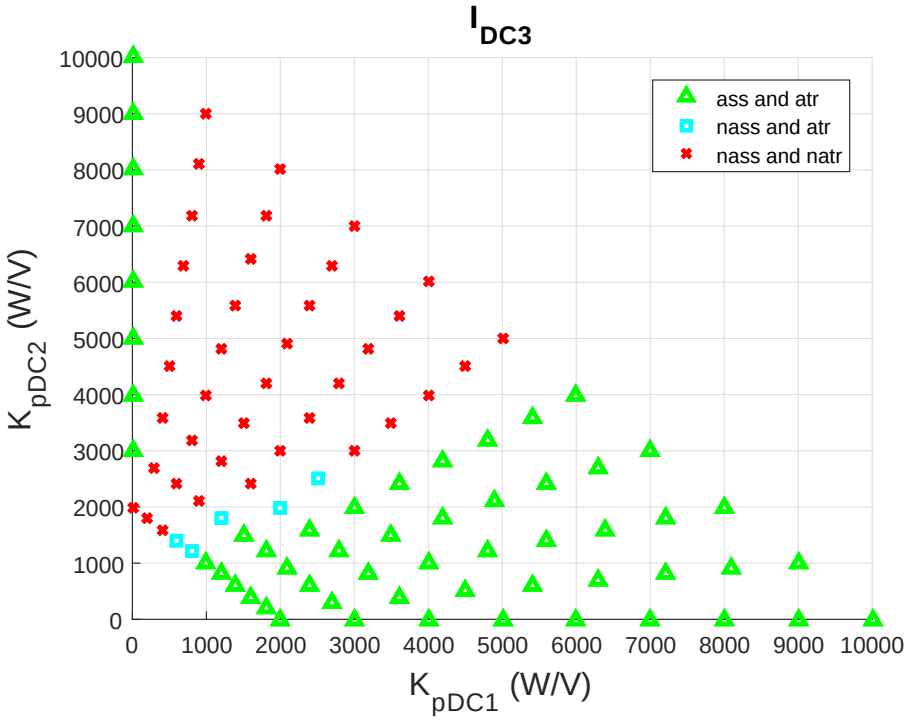

Figure B.108: Admissibility graph of current I_{DC3} from simulation 6 of Case 2

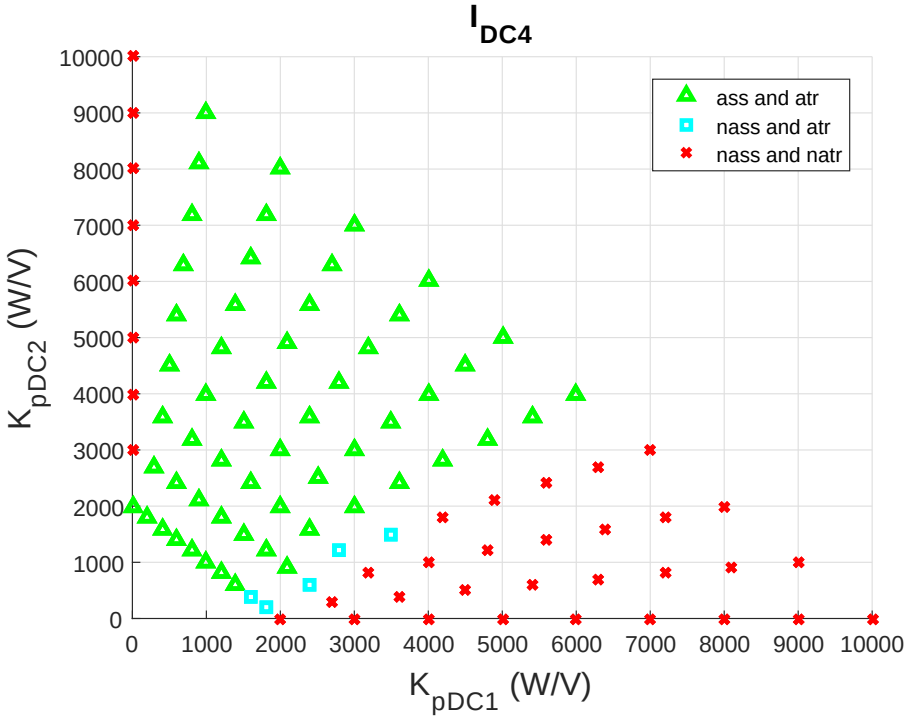

Figure B.109: Admissibility graph of current I_{DC4} from simulation 6 of Case 2

B.6.2 Voltages and currents of power converter 1

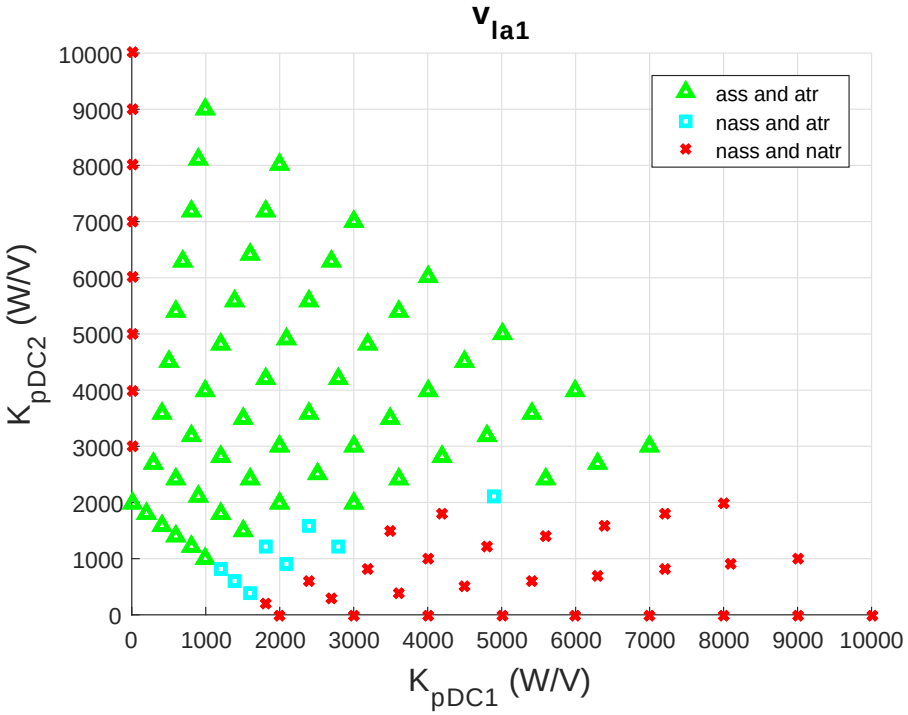

Figure B.110: Admissibility graph of voltage v_{la1} from simulation 6 of Case 2

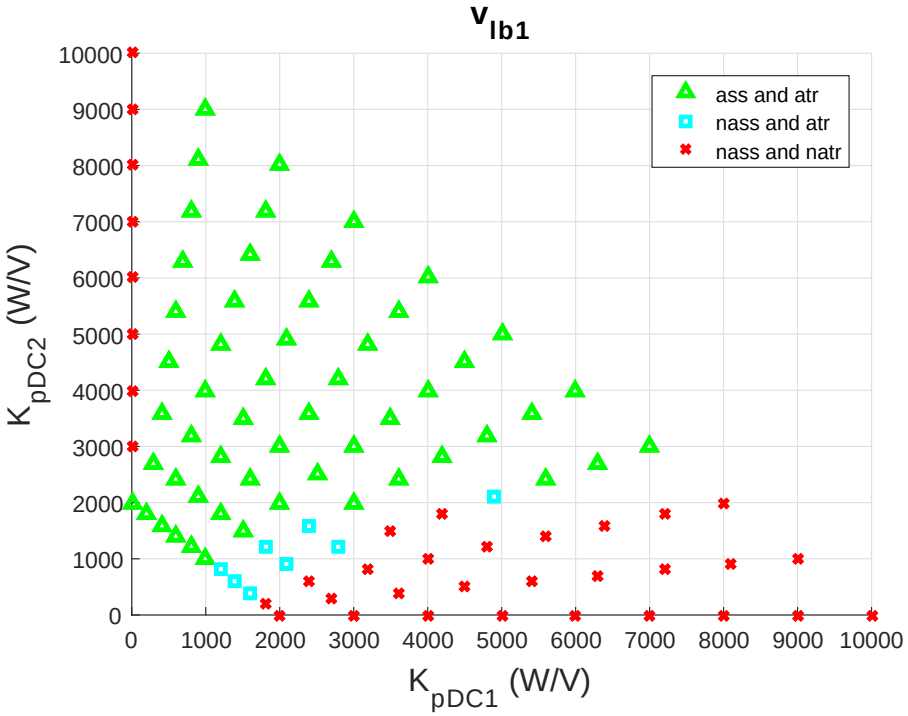

Figure B.111: Admissibility graph of voltage v_{lb1} from simulation 6 of Case 2

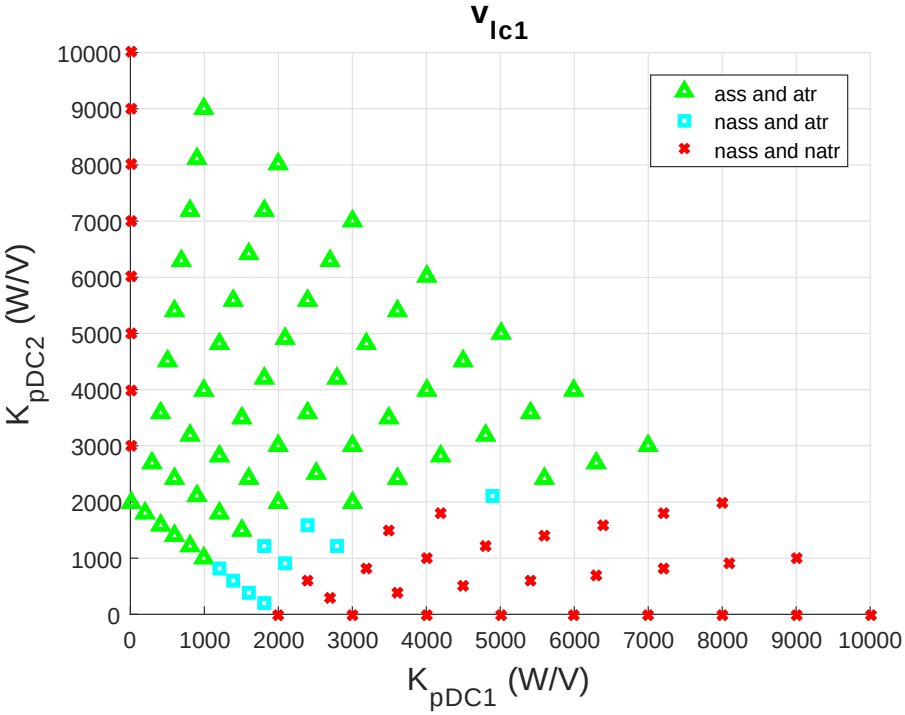

Figure B.112: Admissibility graph of voltage v_{lc1} from simulation 6 of Case 2

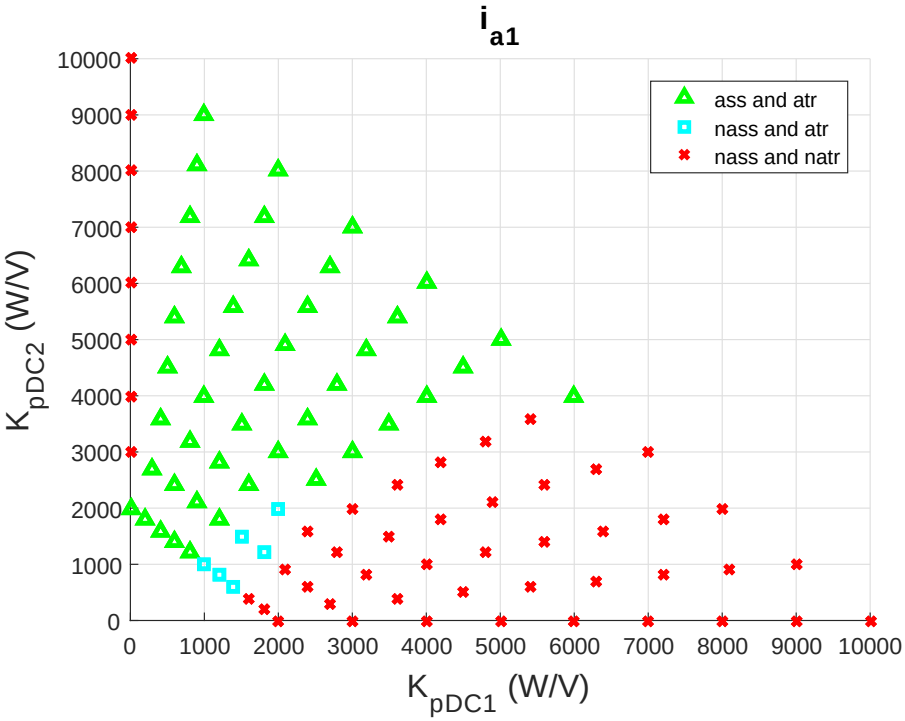

Figure B.113: Admissibility graph of current i_{a1} from simulation 6 of Case 2

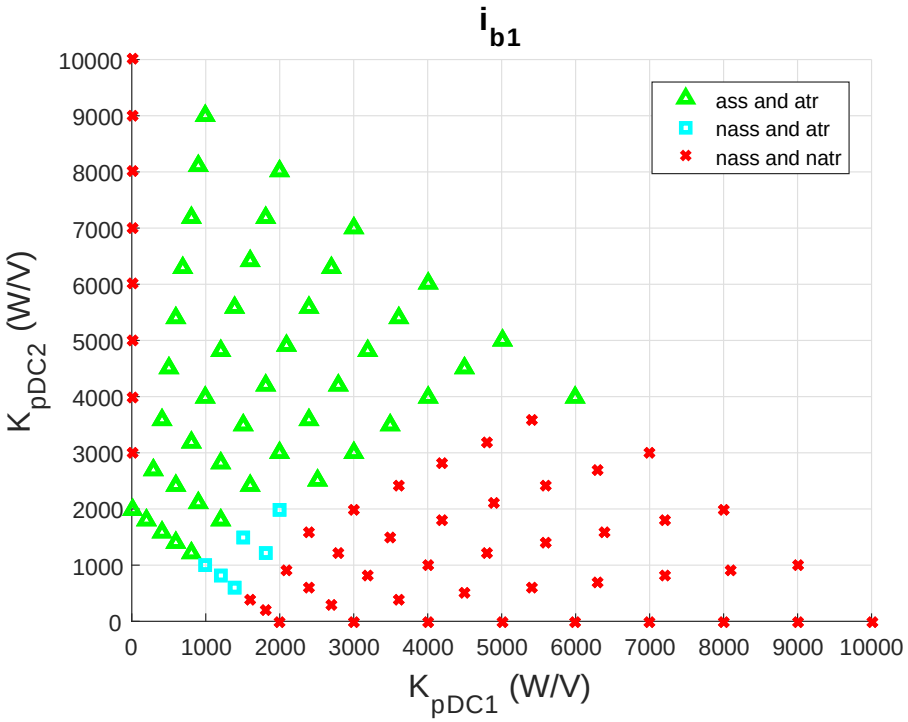

Figure B.114: Admissibility graph of current i_{b1} from simulation 6 of Case 2

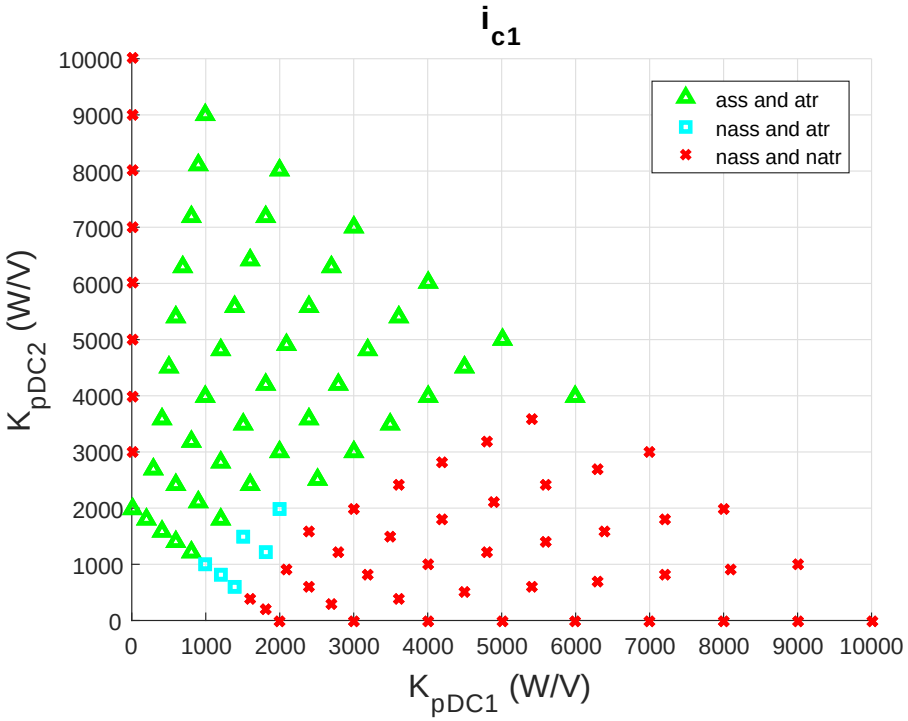

Figure B.115: Admissibility graph of current i_{c1} from simulation 6 of Case 2

B.6.3 Voltages and currents of power converter 2

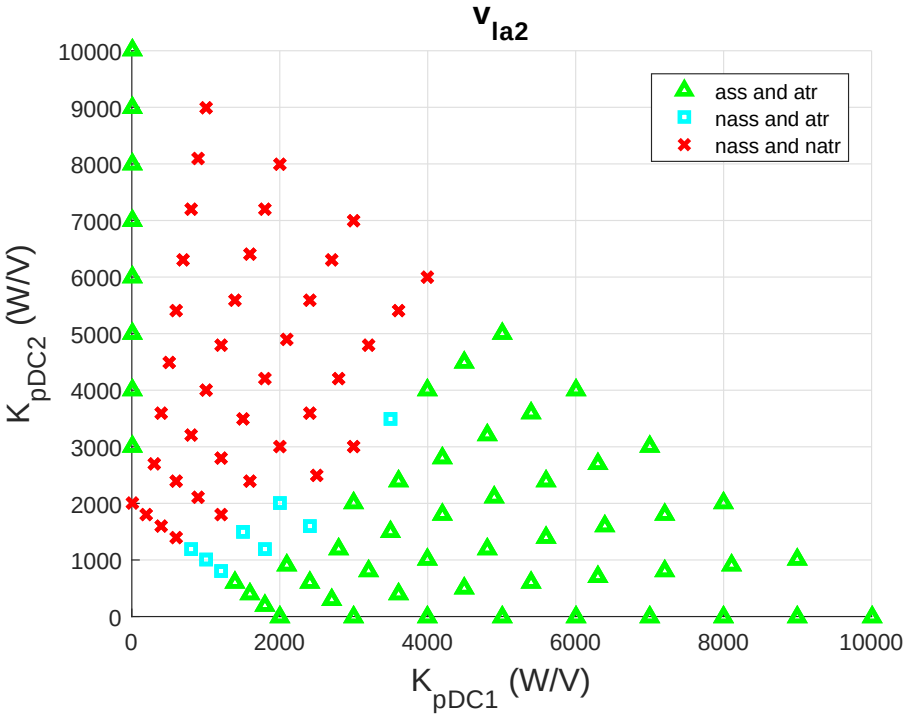

Figure B.116: Admissibility graph of voltage v_{la2} from simulation 6 of Case 2

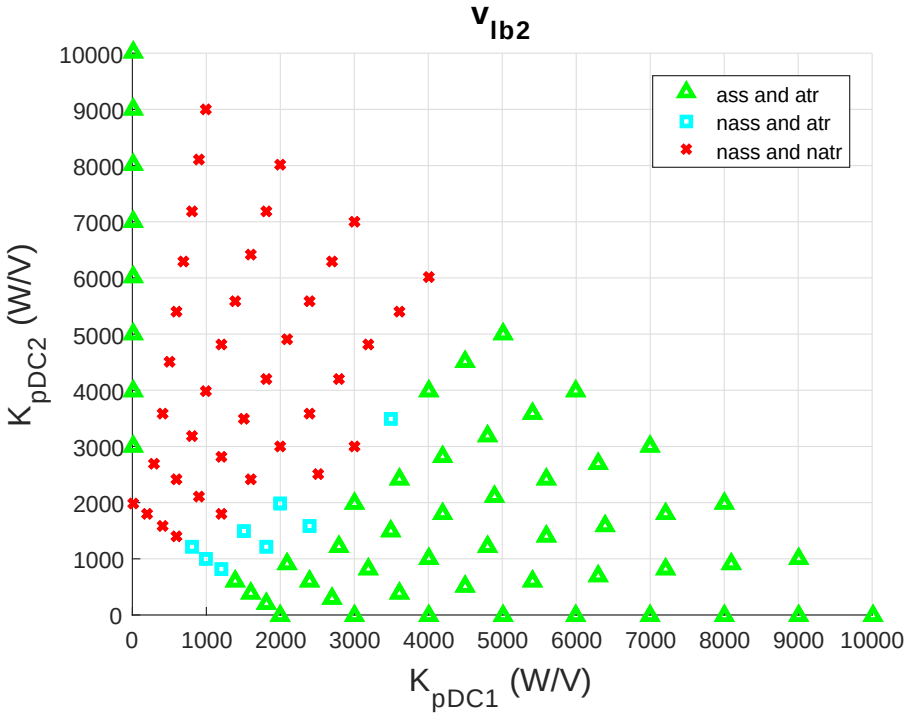

Figure B.117: Admissibility graph of voltage v_{lb2} from simulation 6 of Case 2

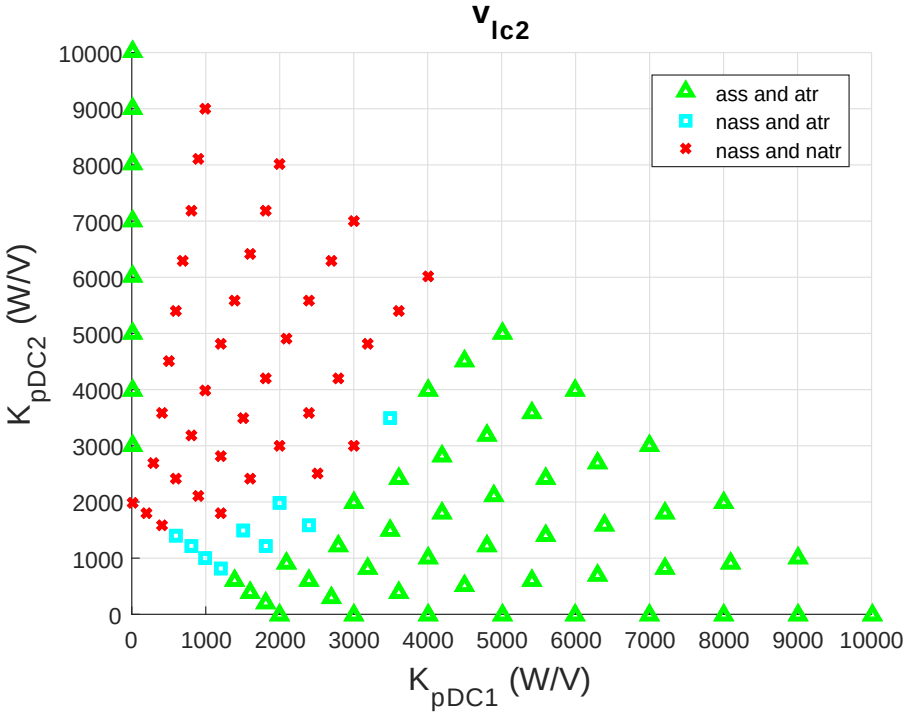

Figure B.118: Admissibility graph of voltage v_{lc2} from simulation 6 of Case 2

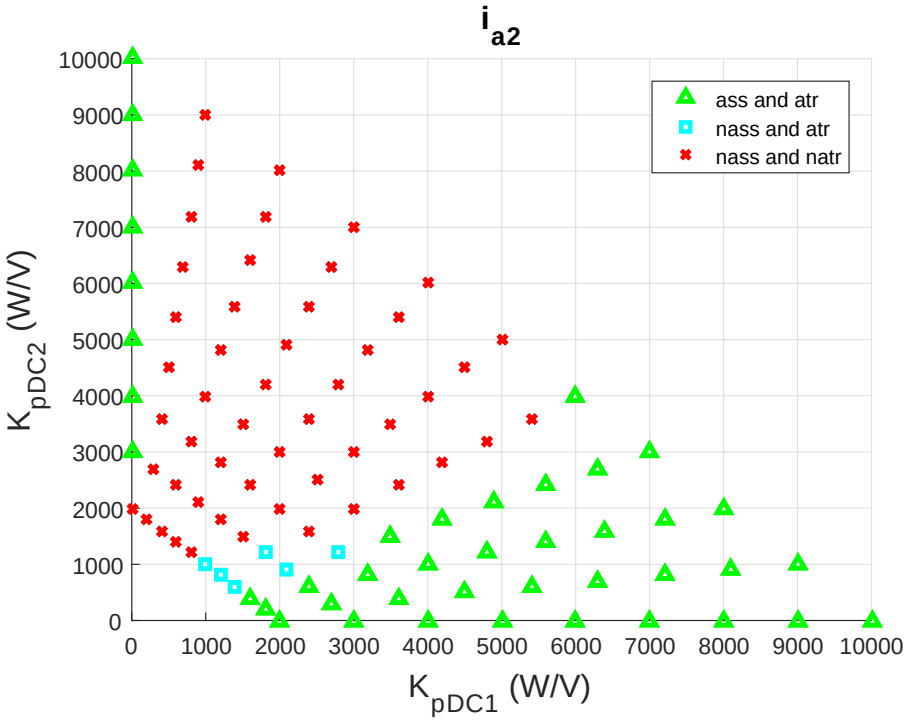

Figure B.119: Admissibility graph of current i_{a2} from simulation 6 of Case 2

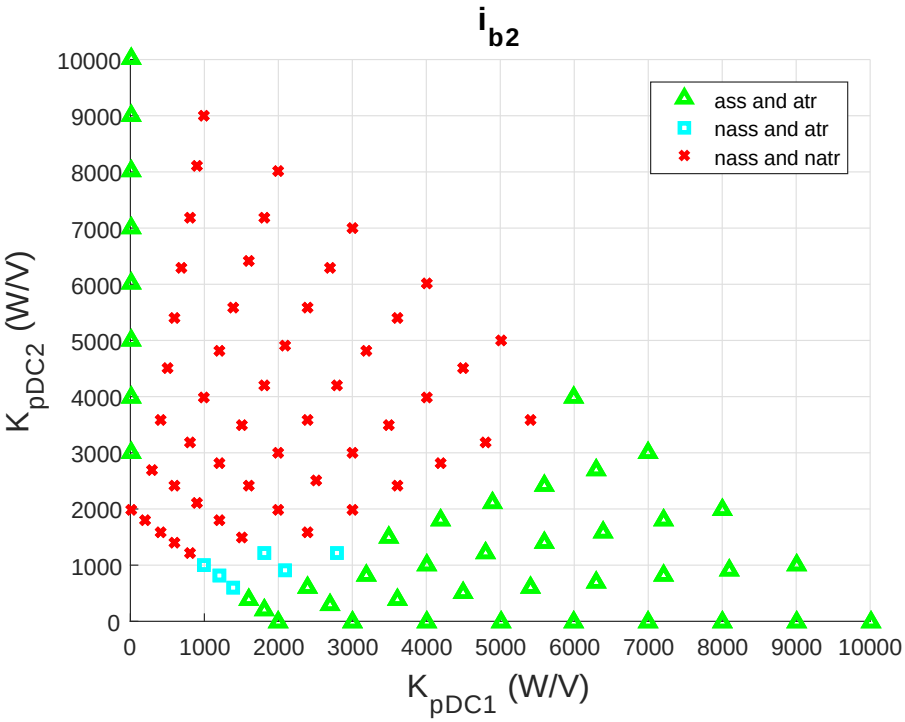

Figure B.120: Admissibility graph of current i_{b2} from simulation 6 of Case 2

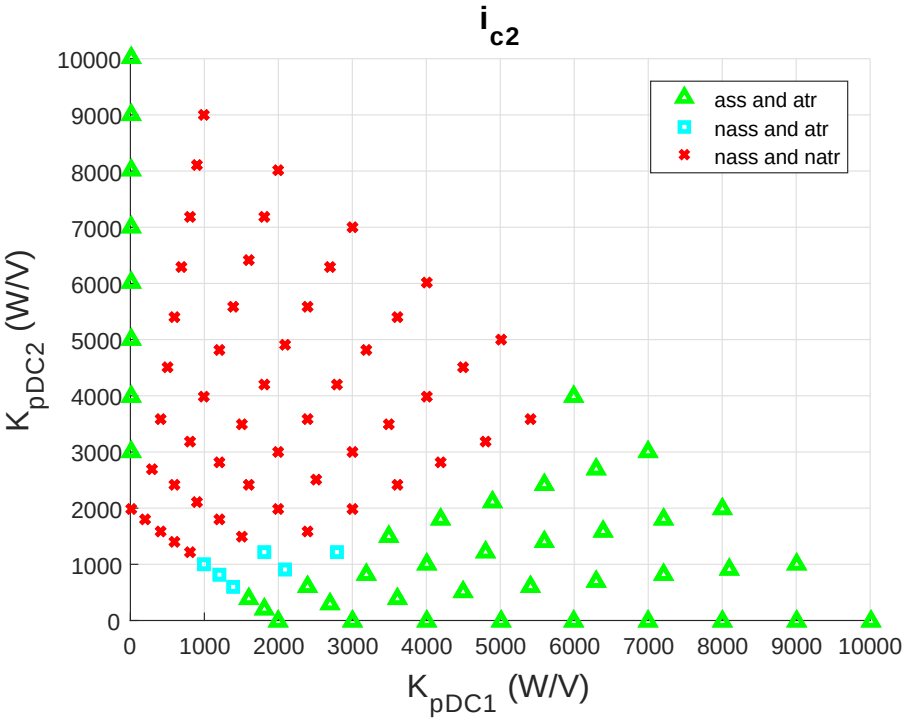

Figure B.121: Admissibility graph of current i_{c2} from simulation 6 of Case 2

B.7 Simulation 7

Simulation 7: $K_{pDC} \in [11000, 70000]$ with a step of 5900. In total 121 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.7.1 Voltages and currents of the multi-terminal HVDC grid

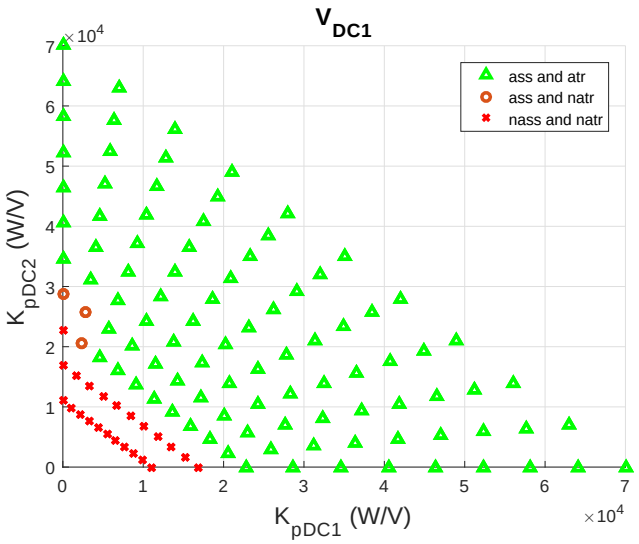

Figure B.122: Admissibility graph of voltage V_{DC1} from simulation 7 of Case 2

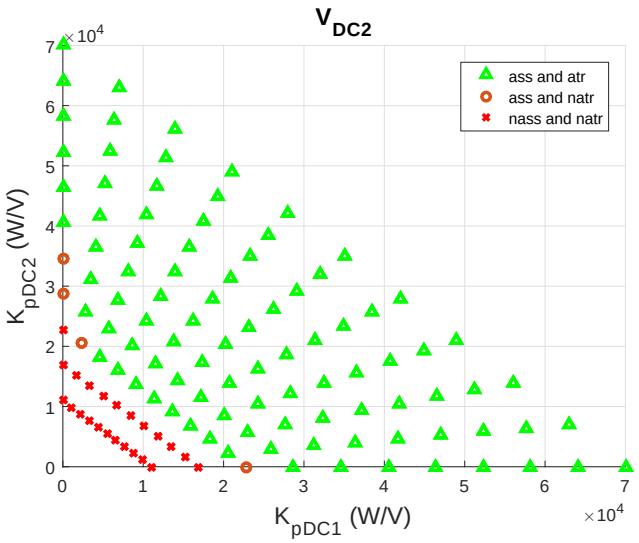

Figure B.123: Admissibility graph of voltage V_{DC2} from simulation 7 of Case 2

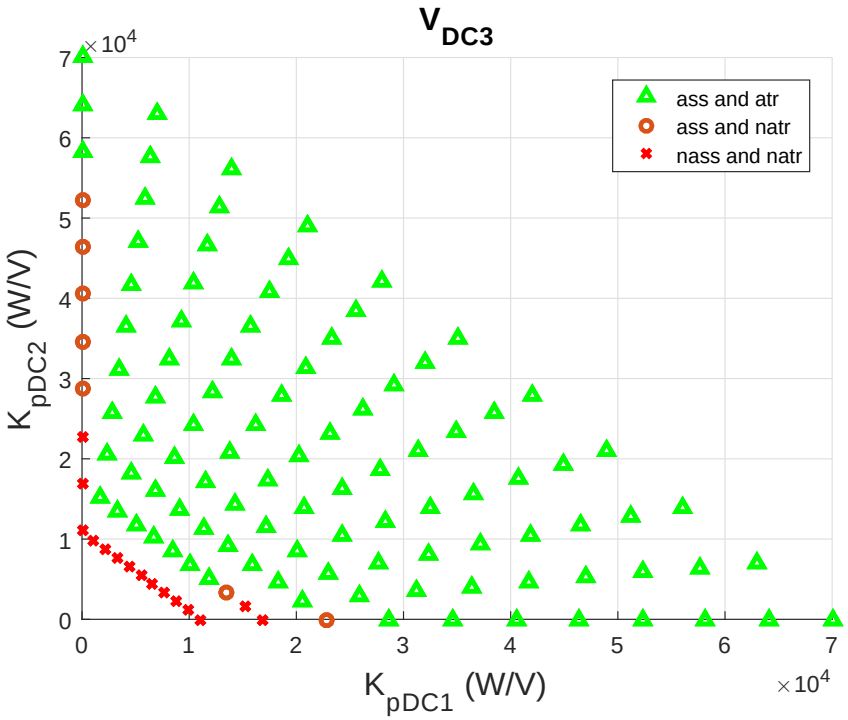

Figure B.124: Admissibility graph of voltage V_{DC3} from simulation 7 of Case 2

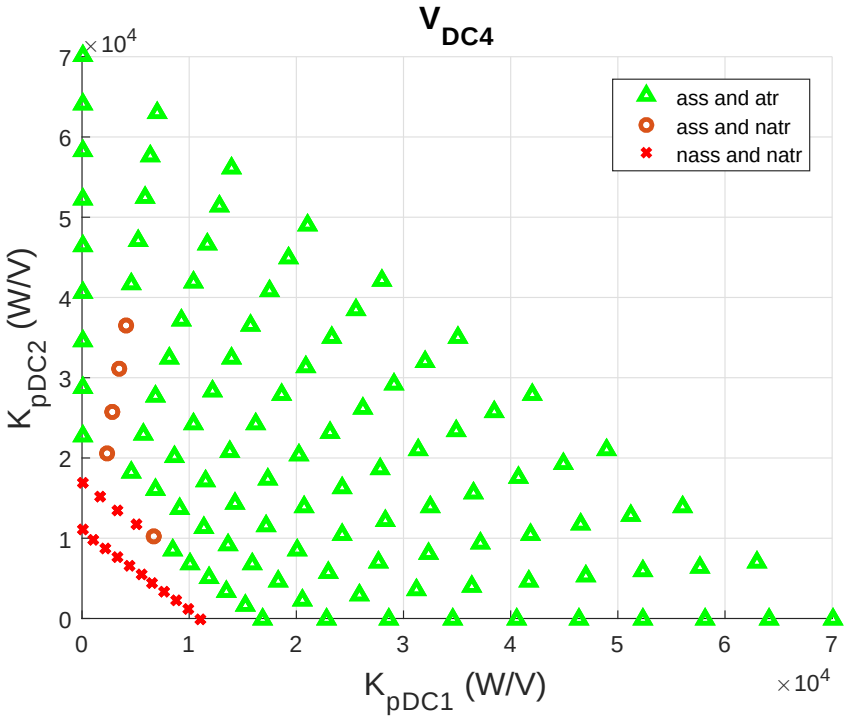

Figure B.125: Admissibility graph of voltage V_{DC4} from simulation 7 of Case 2

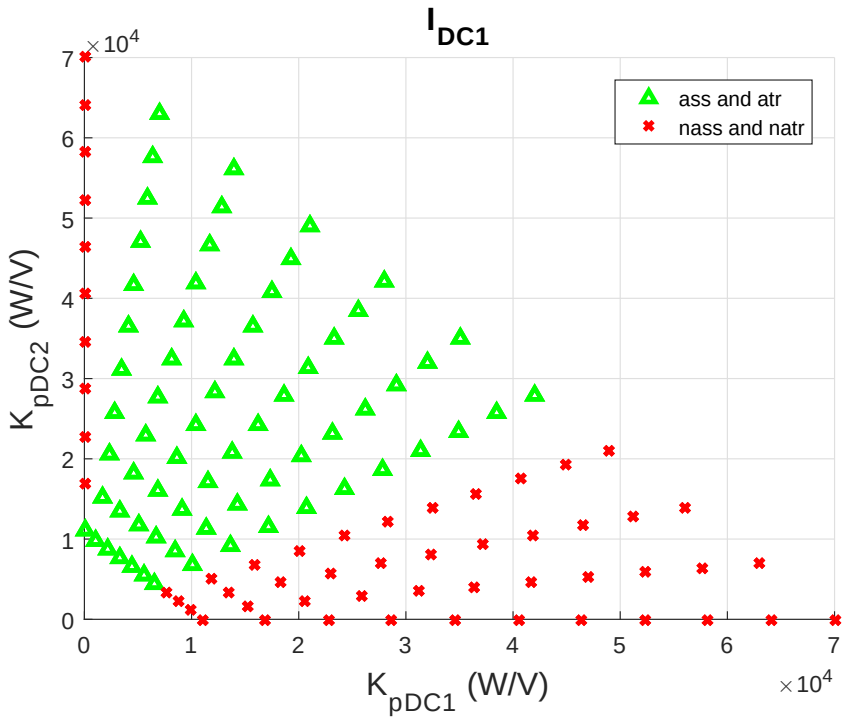

Figure B.126: Admissibility graph of current I_{DC1} from simulation 7 of Case 2

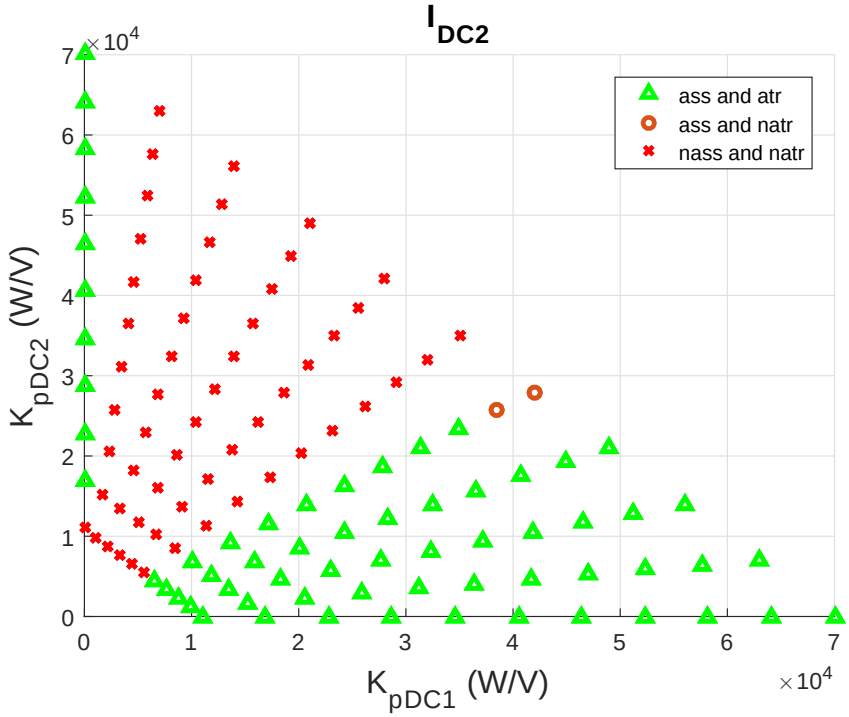

Figure B.127: Admissibility graph of current I_{DC2} from simulation 7 of Case 2

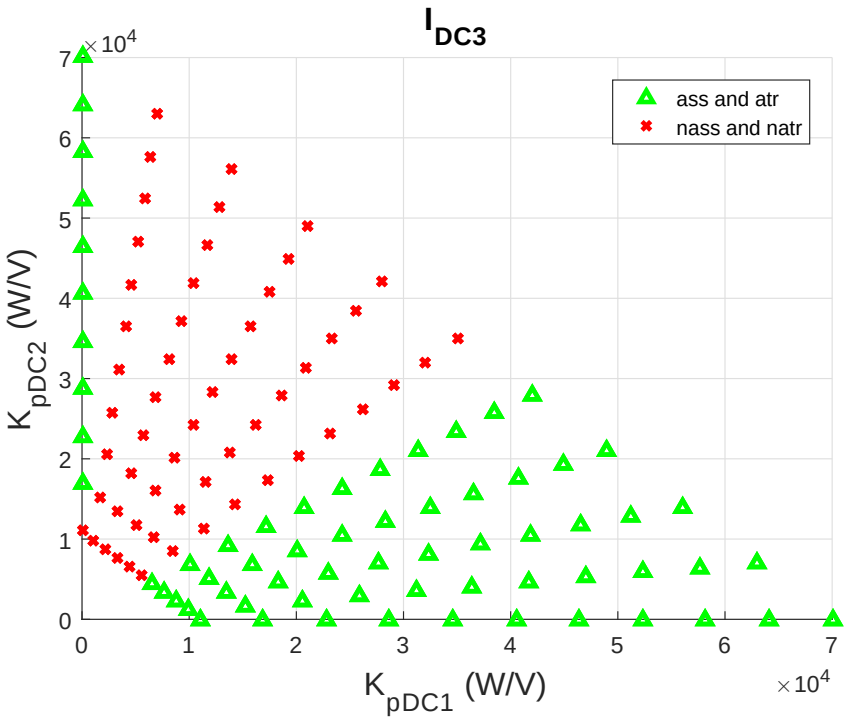

Figure B.128: Admissibility graph of current I_{DC3} from simulation 7 of Case 2

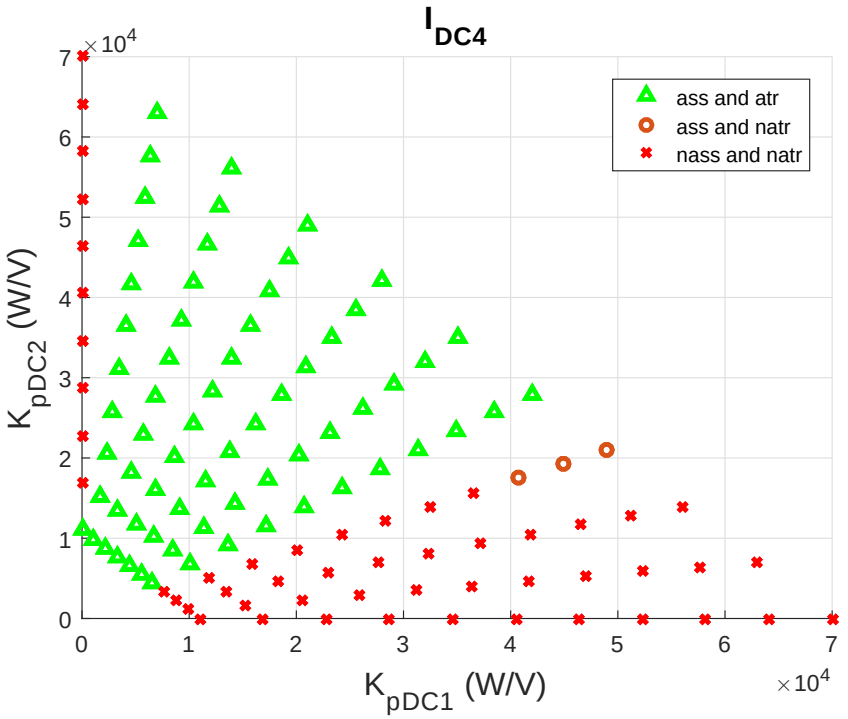

Figure B.129: Admissibility graph of current I_{DC4} from simulation 7 of Case 2

B.7.2 Voltages and currents of power converter 1

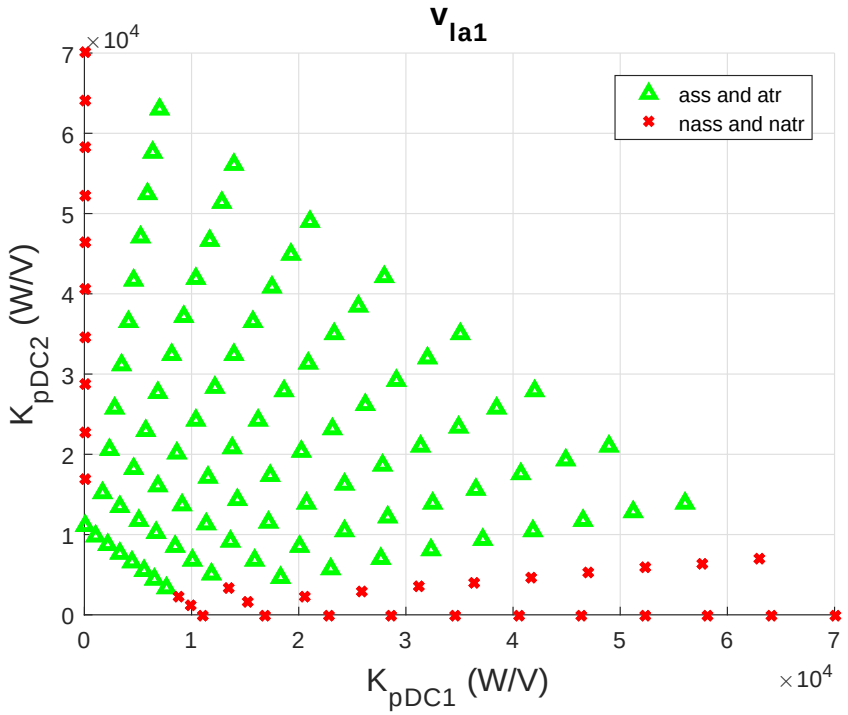

Figure B.130: Admissibility graph of voltage v_{la1} from simulation 7 of Case 2

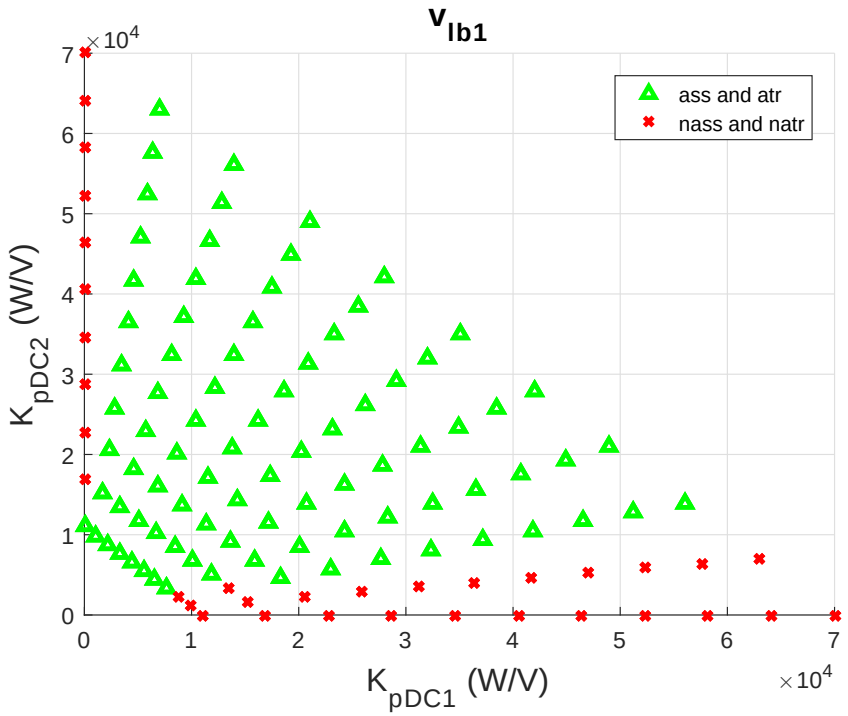

Figure B.131: Admissibility graph of voltage v_{lb1} from simulation 7 of Case 2

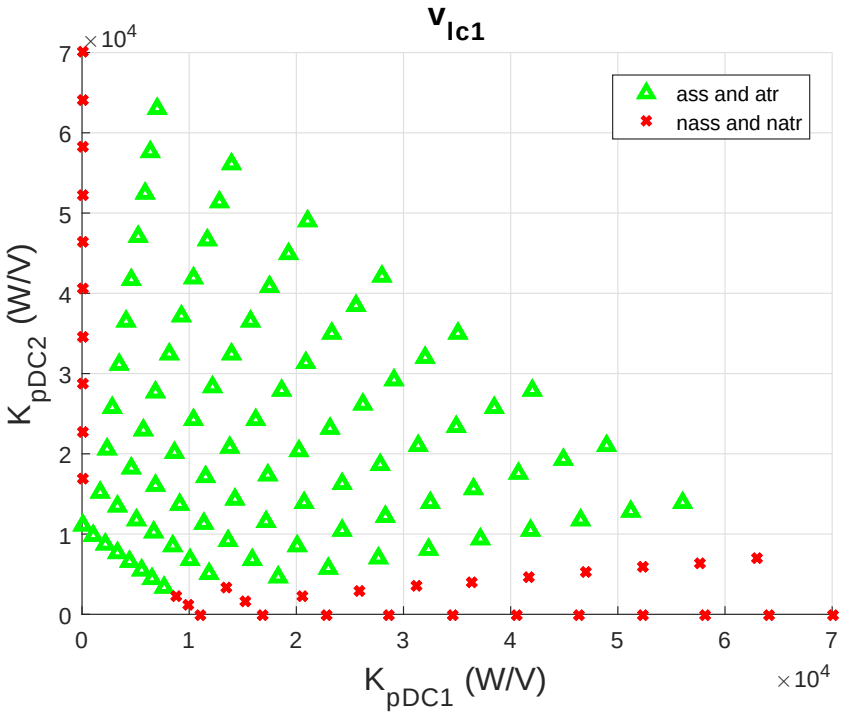

Figure B.132: Admissibility graph of current v_{lc1} from simulation 7 of Case 2

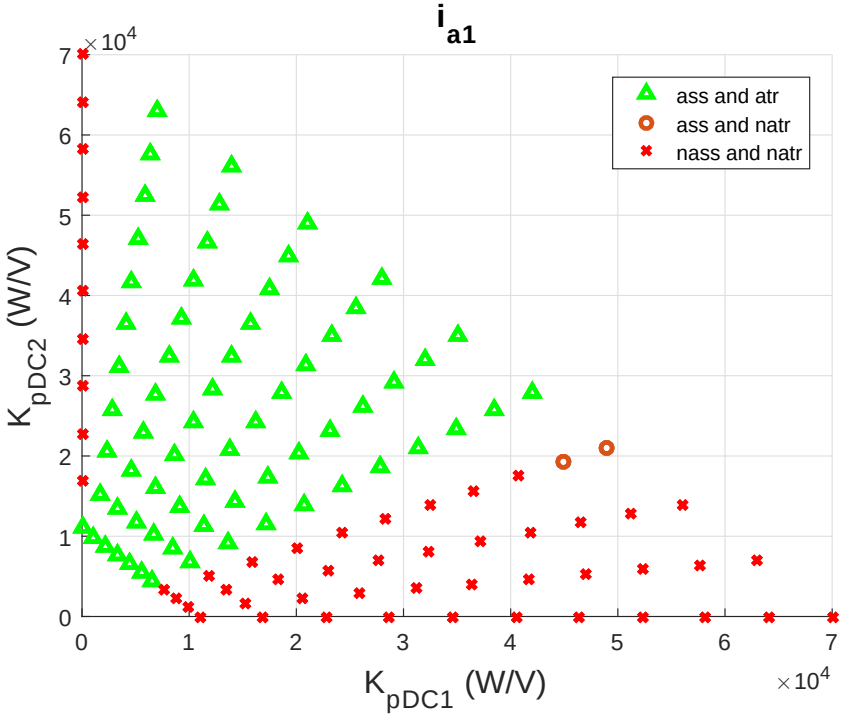

Figure B.133: Admissibility graph of current i_{a1} from simulation 7 of Case 2

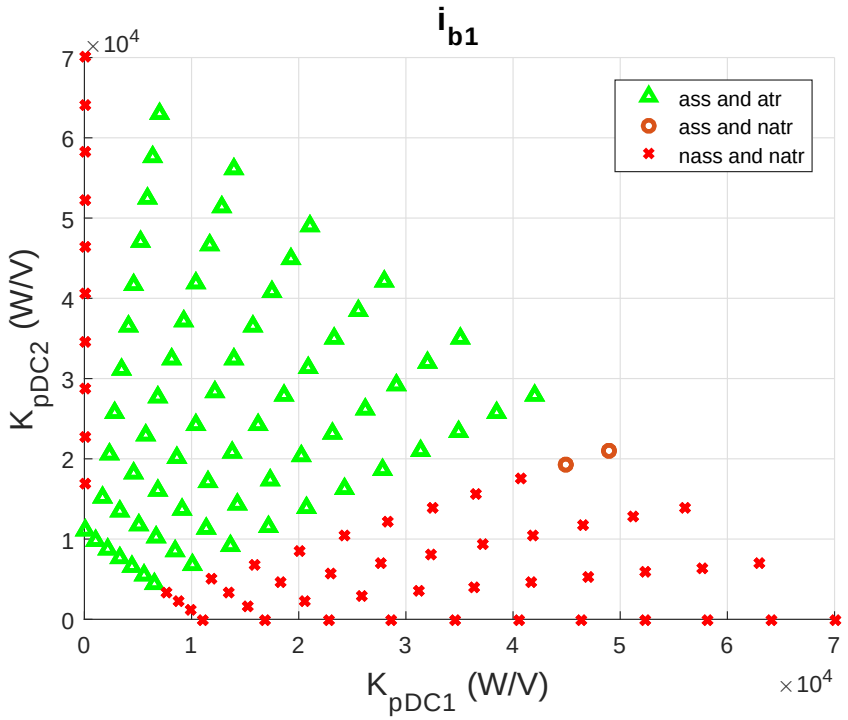

Figure B.134: Admissibility graph of current i_{b1} from simulation 7 of Case 2

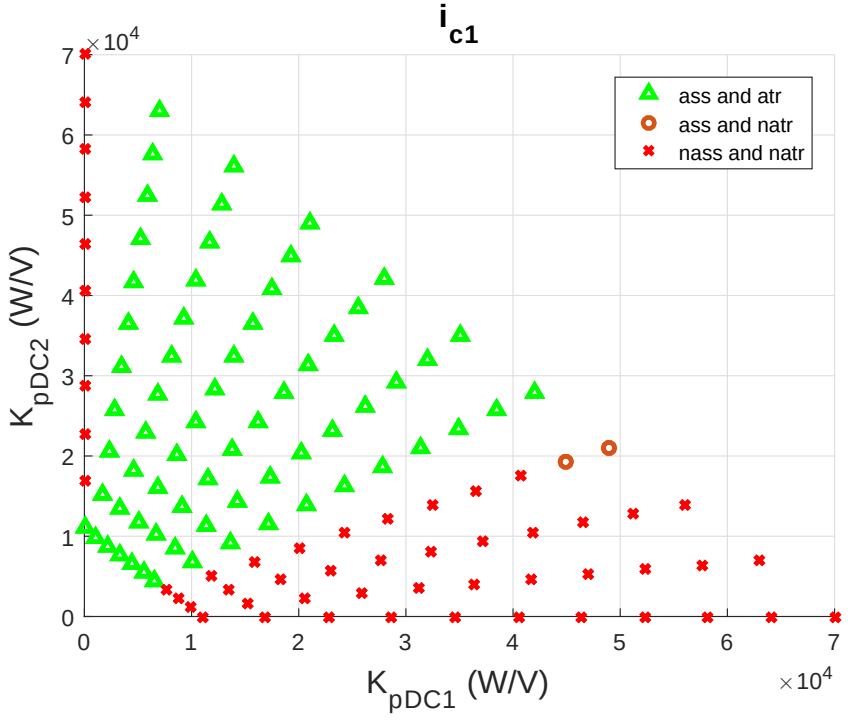

Figure B.135: Admissibility graph of current i_{c1} from simulation 7 of Case 2

B.7.3 Voltages and currents of power converter 2

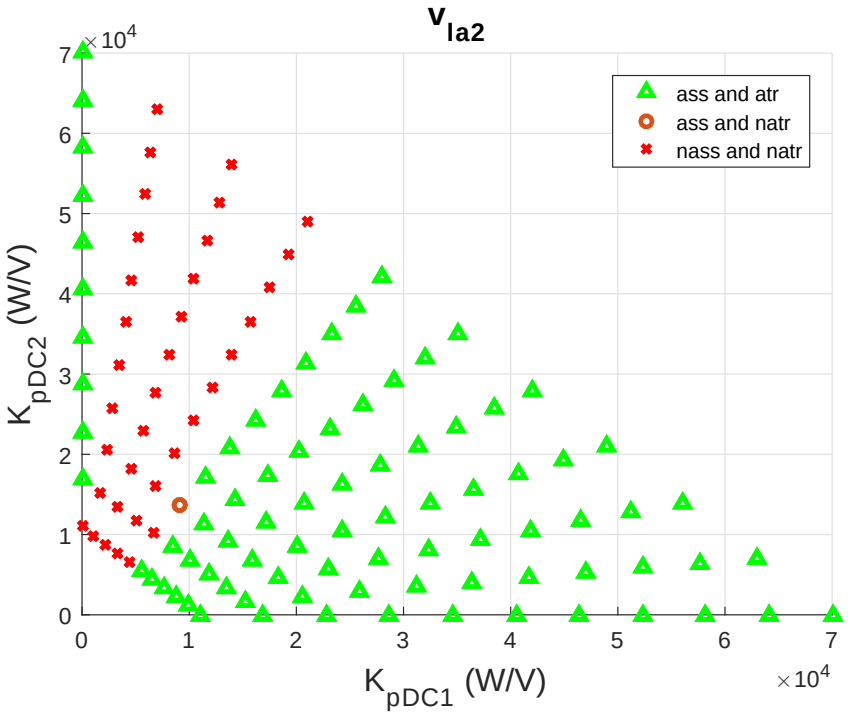

Figure B.136: Admissibility graph of voltage v_{la2} from simulation 7 of Case 2

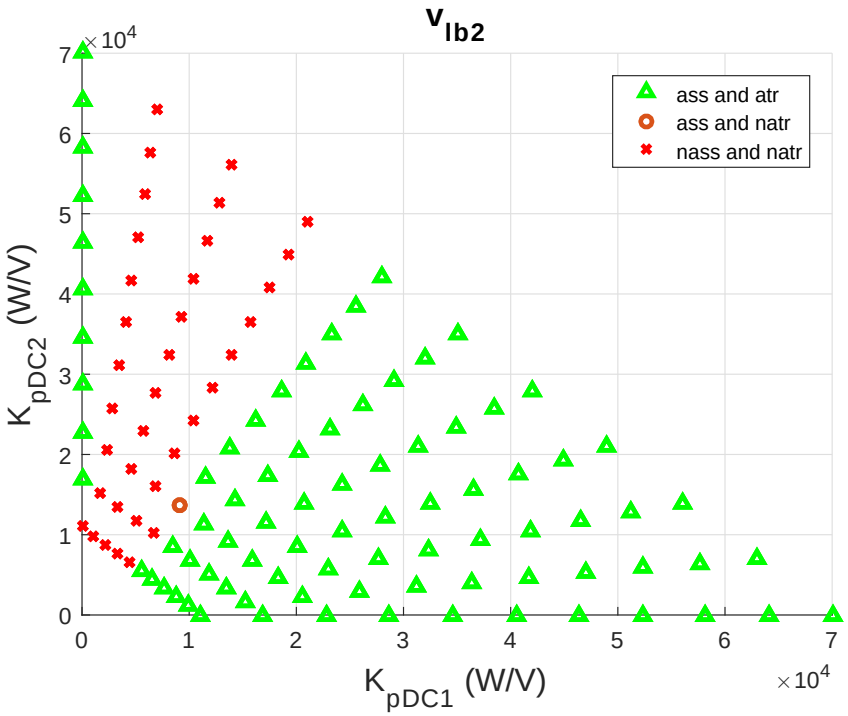

Figure B.137: Admissibility graph of voltage v_{lb2} from simulation 7 of Case 2

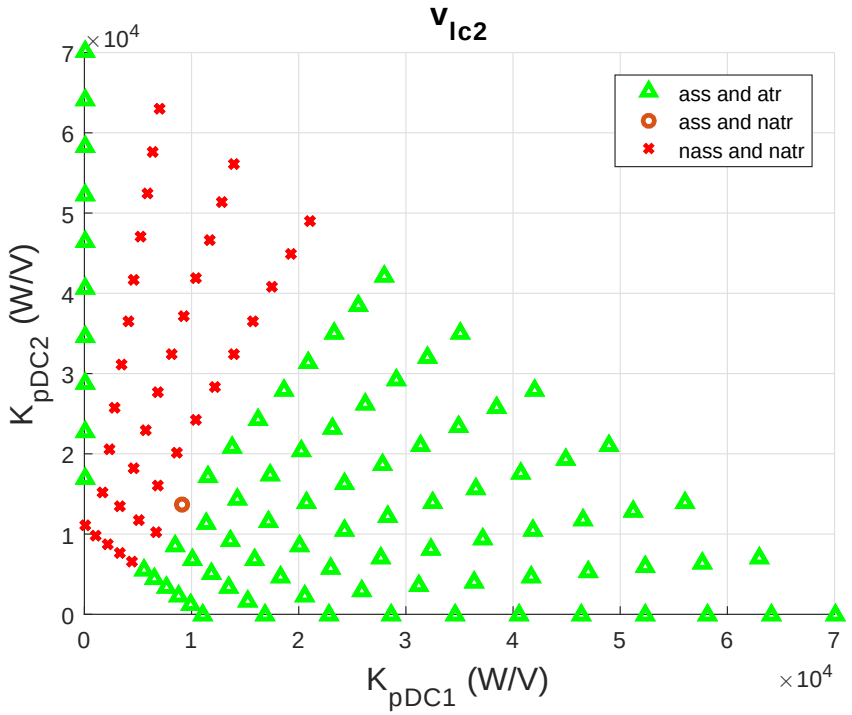

Figure B.138: Admissibility graph of voltage v_{lc2} from simulation 7 of Case 2

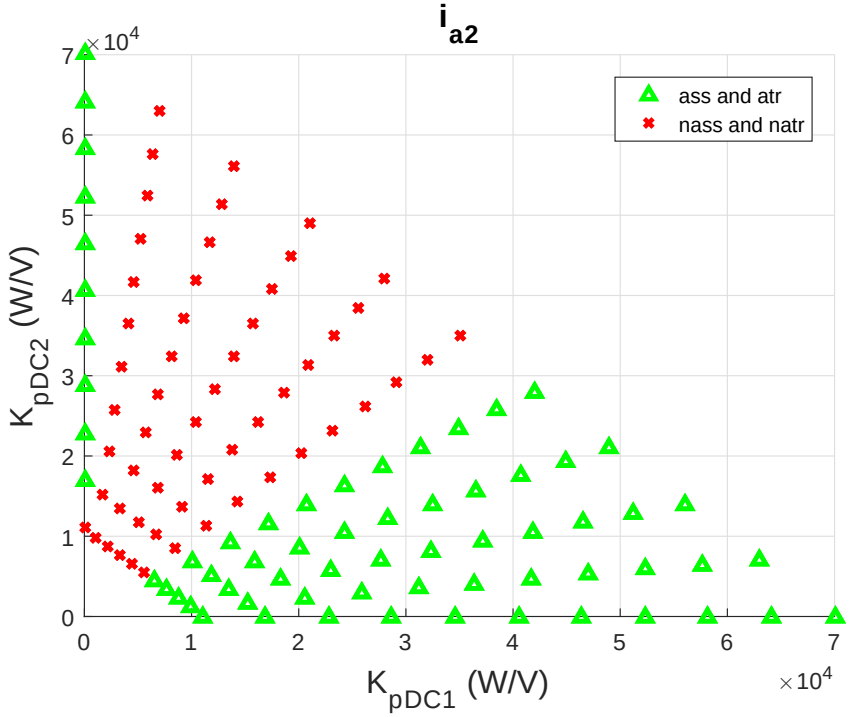

Figure B.139: Admissibility graph of current i_{a2} from simulation 7 of Case 2

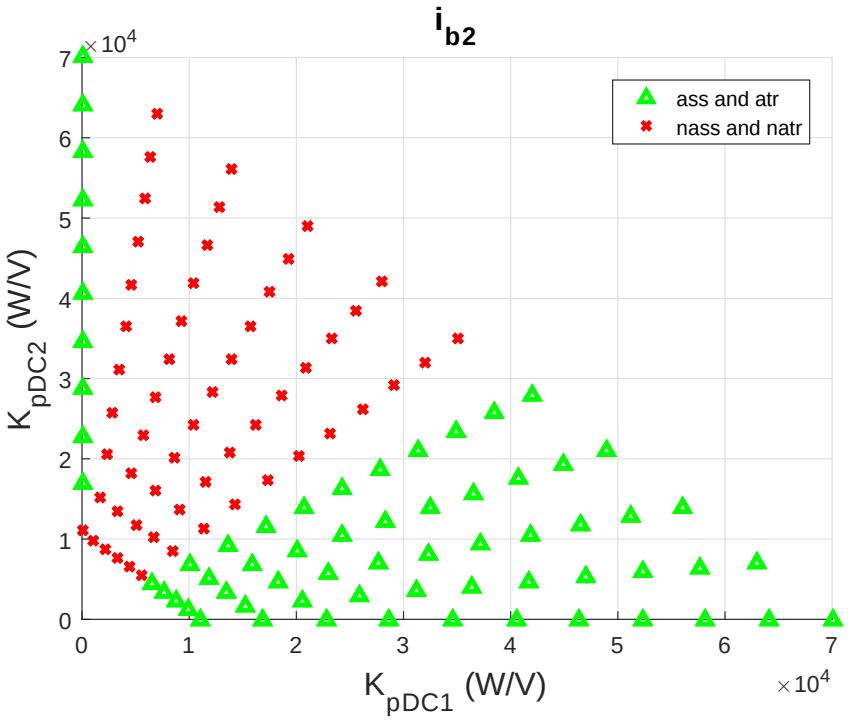

Figure B.140: Admissibility graph of current i_{b2} from simulation 7 of Case 2

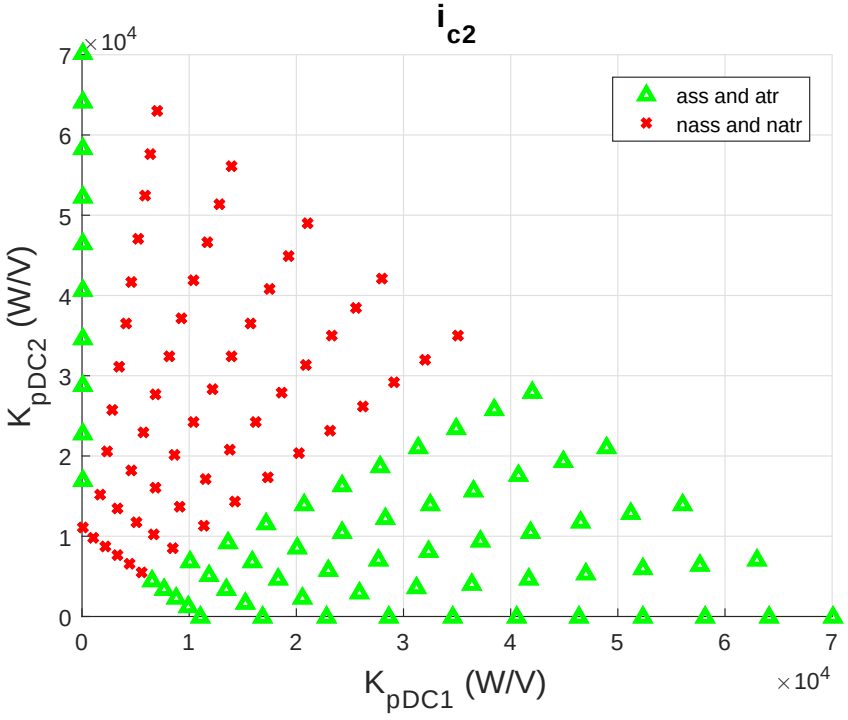

Figure B.141: Admissibility graph of current i_{c2} from simulation 7 of Case 2

B.8 Simulation 8

Simulation 8: $K_{pDC} \in [75000, 150000]$ with a step of 7500. In total 121 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.8.1 Voltages and currents of the multi-terminal HVDC grid

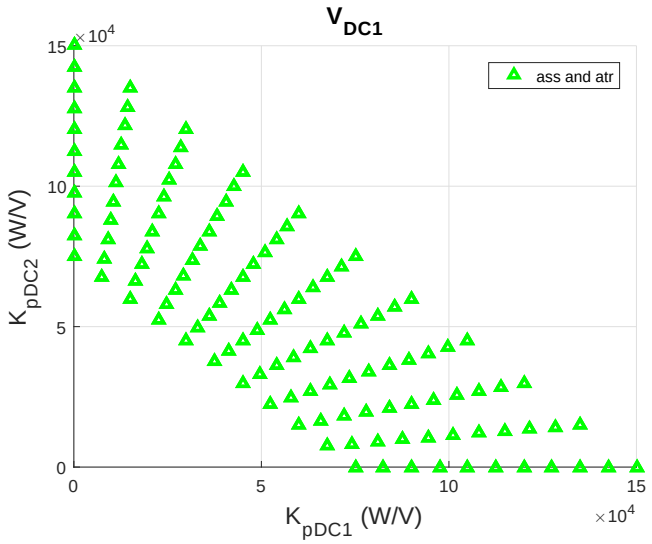

Figure B.142: Admissibility graph of voltage V_{DC1} from simulation 8 of Case 2

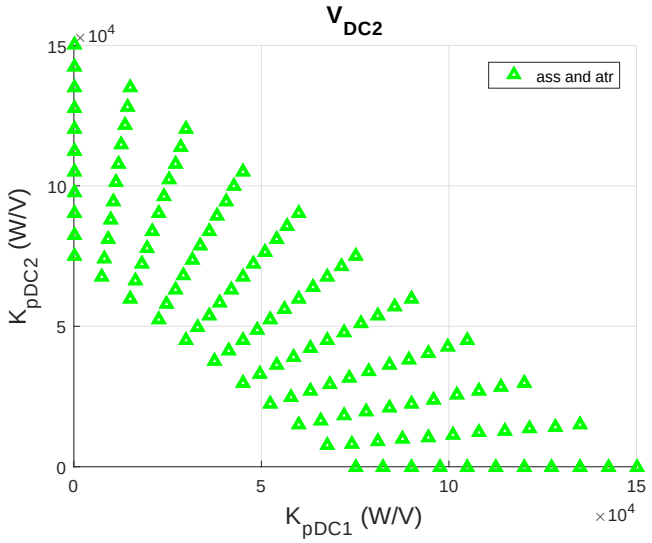

Figure B.143: Admissibility graph of voltage V_{DC2} from simulation 8 of Case 2

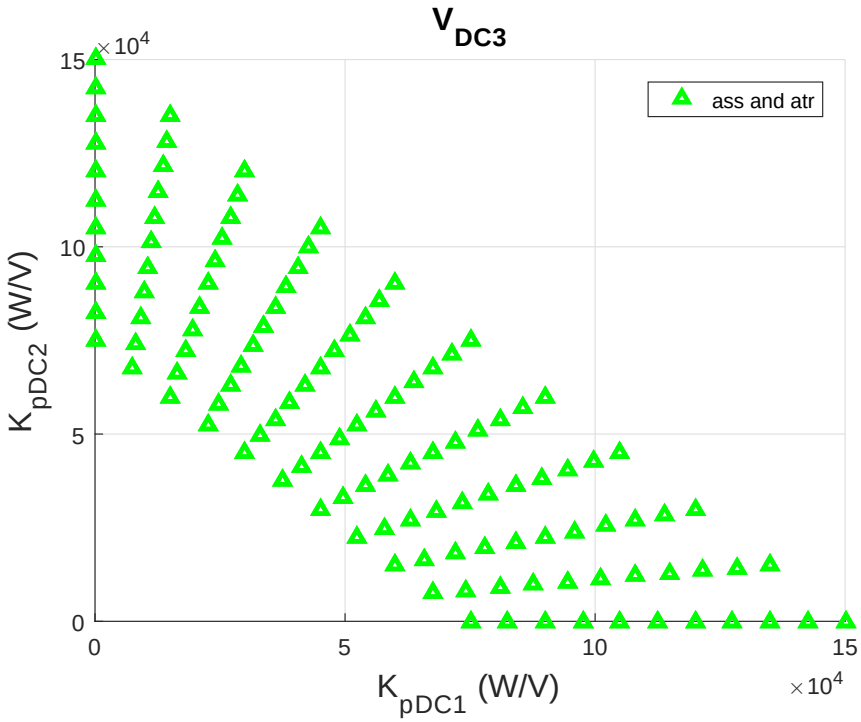

Figure B.144: Admissibility graph of voltage V_{DC3} from simulation 8 of Case 2

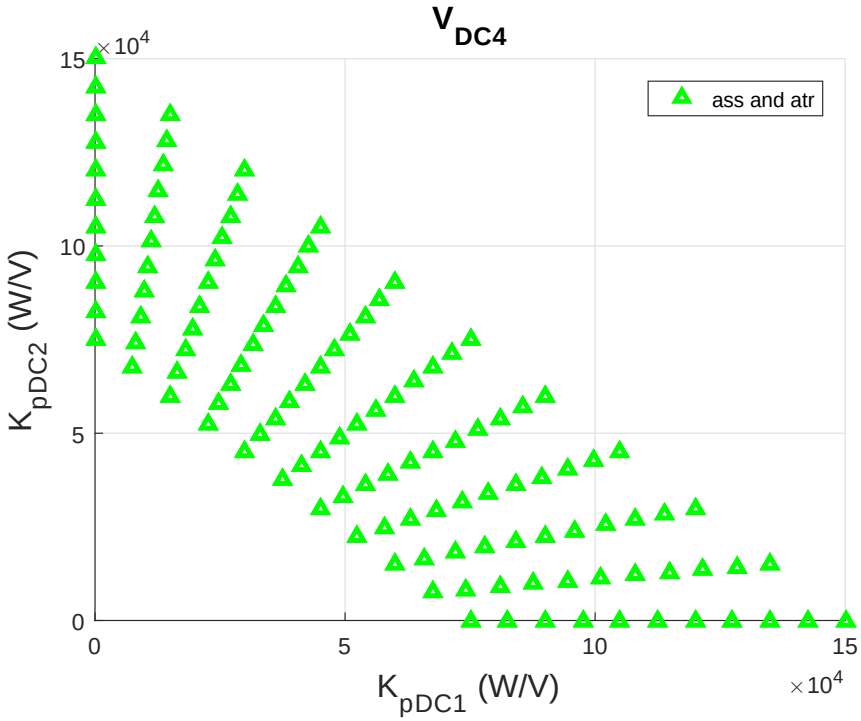

Figure B.145: Admissibility graph of voltage V_{DC4} from simulation 8 of Case 2

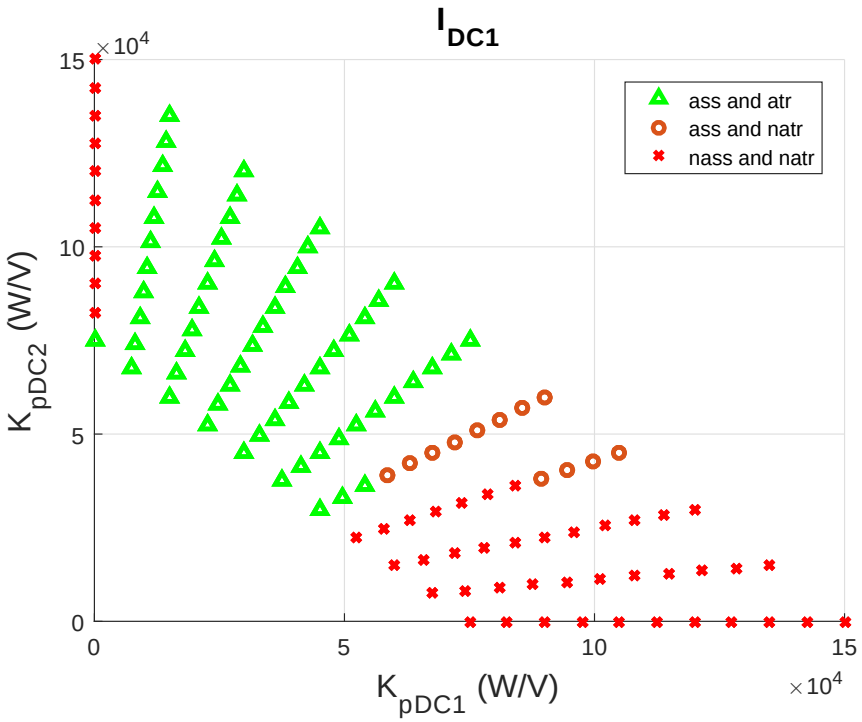

Figure B.146: Admissibility graph of current I_{DC1} from simulation 8 of Case 2

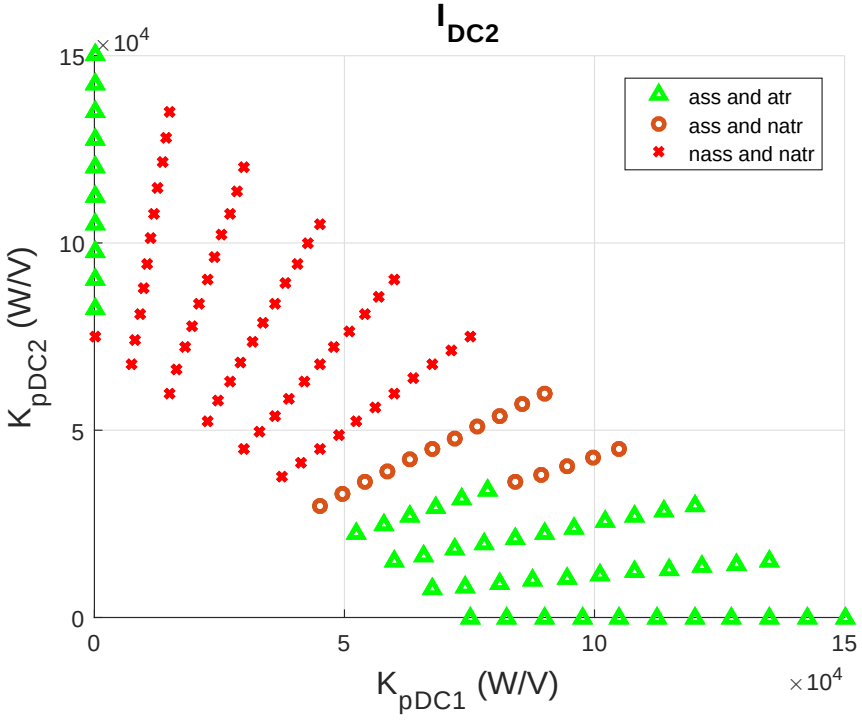

Figure B.147: Admissibility graph of current I_{DC2} from simulation 8 of Case 2

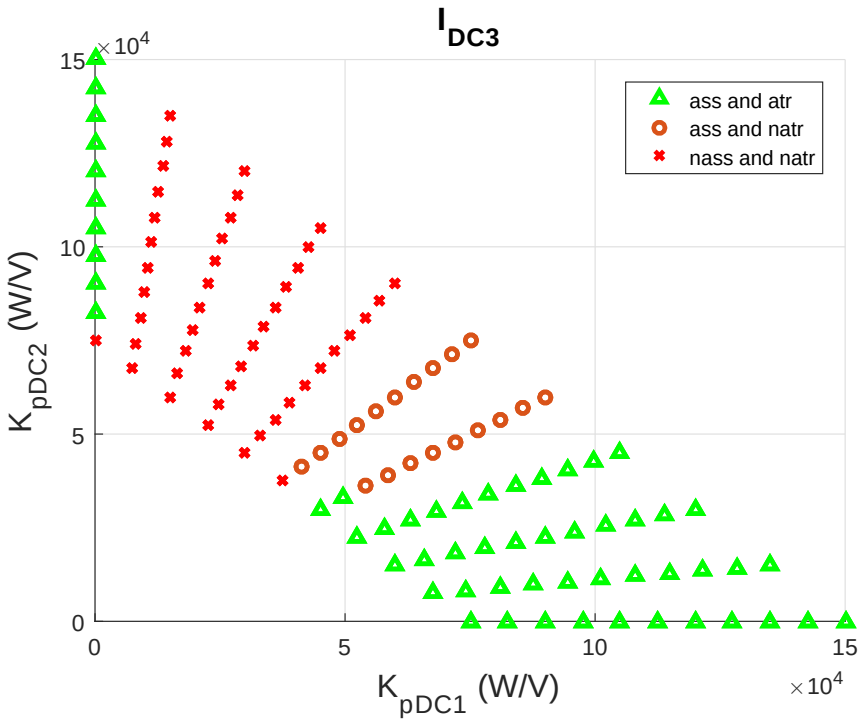

Figure B.148: Admissibility graph of current I_{DC3} from simulation 8 of Case 2

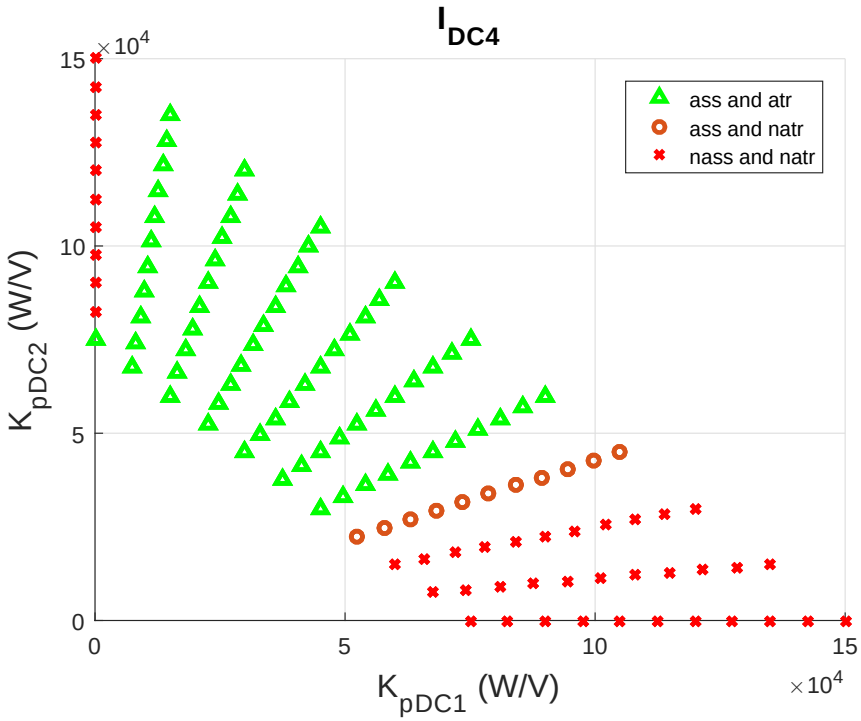

Figure B.149: Admissibility graph of current I_{DC4} from simulation 8 of Case 2

B.8.2 Voltages and currents of power converter 1

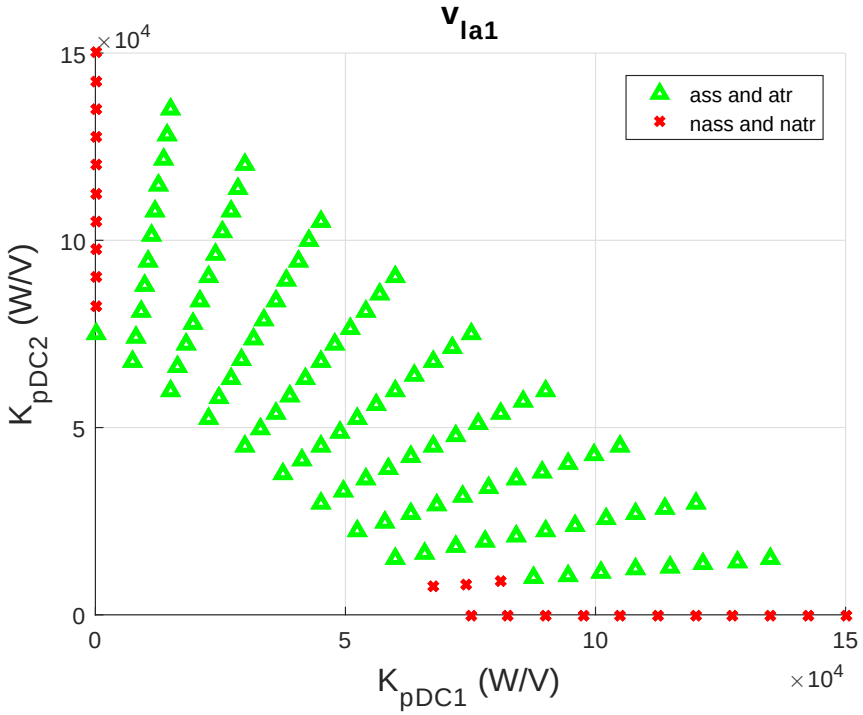

Figure B.150: Admissibility graph of voltage v_{la1} from simulation 8 of Case 2

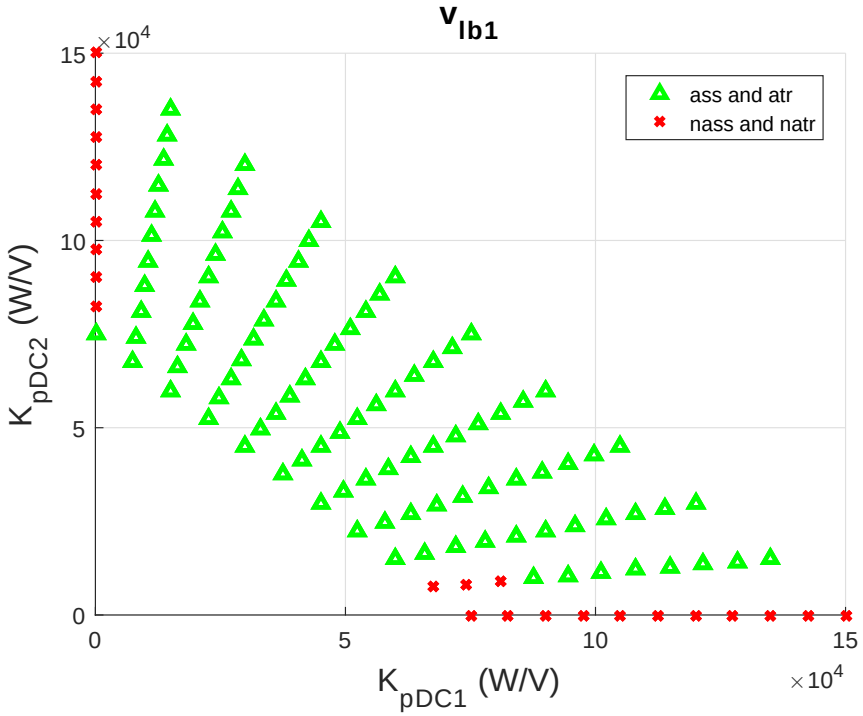

Figure B.151: Admissibility graph of voltage v_{lb1} from simulation 8 of Case 2

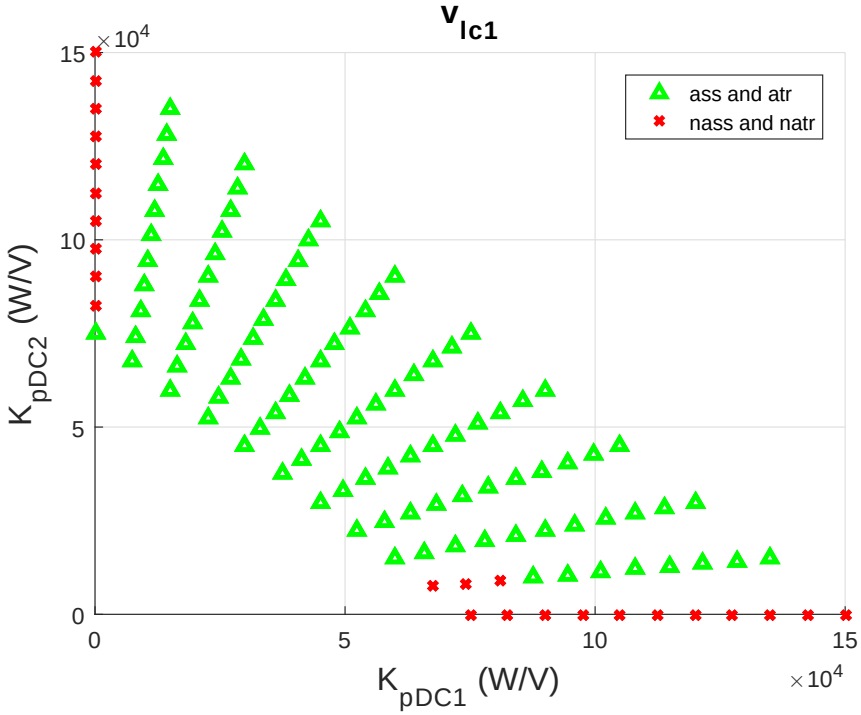

Figure B.152: Admissibility graph of voltage v_{lc1} from simulation 8 of Case 2

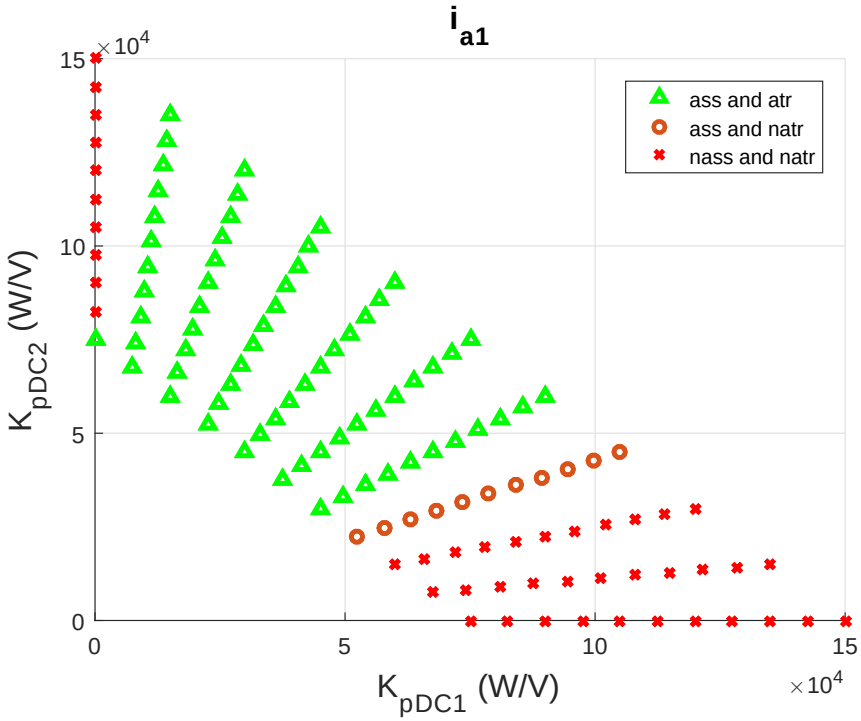

Figure B.153: Admissibility graph of current i_{a1} from simulation 8 of Case 2

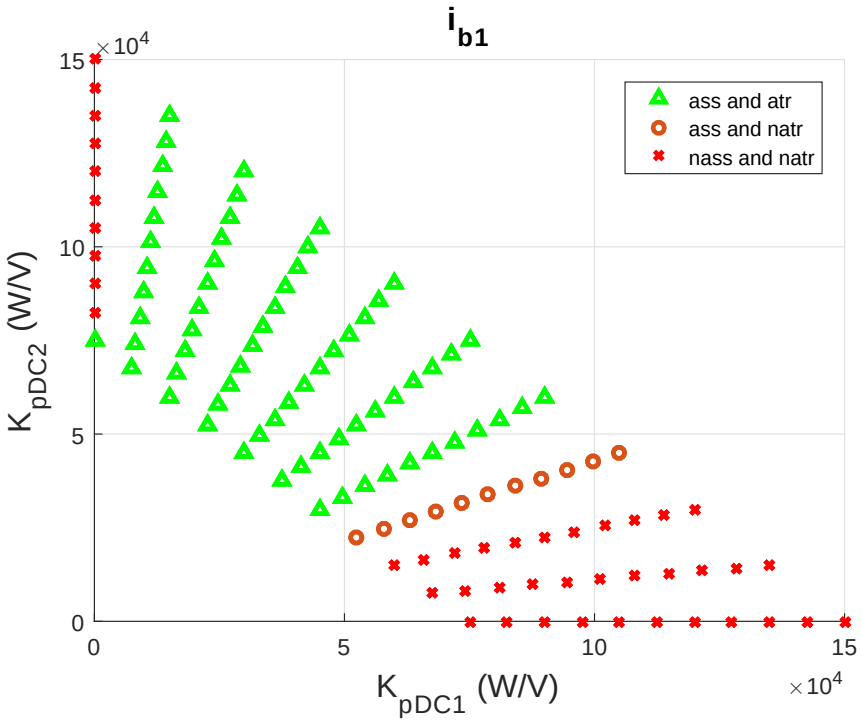

Figure B.154: Admissibility graph of current i_{b1} from simulation 8 of Case 2

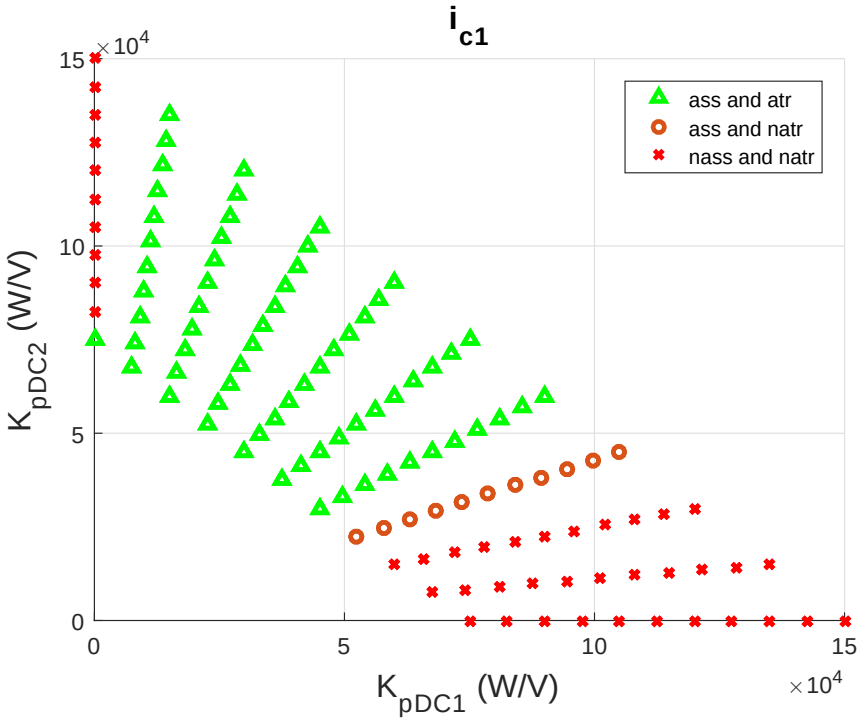

Figure B.155: Admissibility graph of current i_{c1} from simulation 8 of Case 2

B.8.3 Voltages and currents of power converter 2

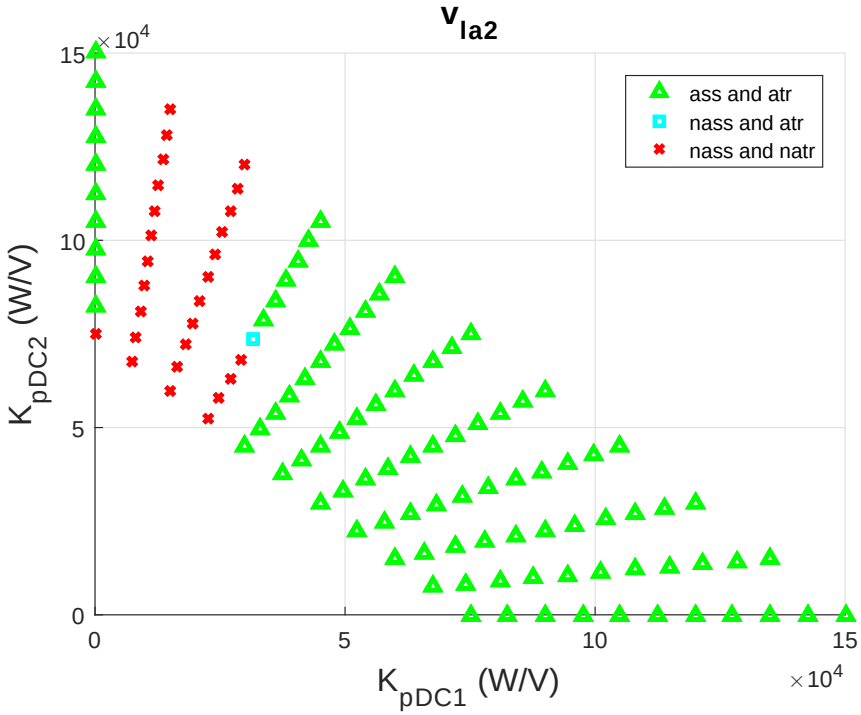

Figure B.156: Admissibility graph of voltage v_{la2} from simulation 8 of Case 2

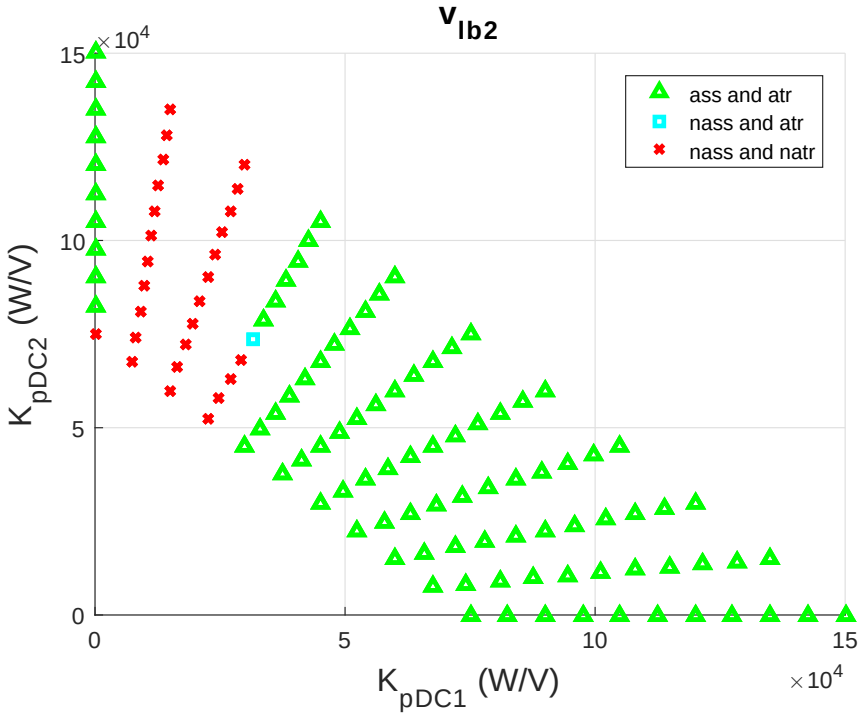

Figure B.157: Admissibility graph of voltage v_{lb2} from simulation 8 of Case 2

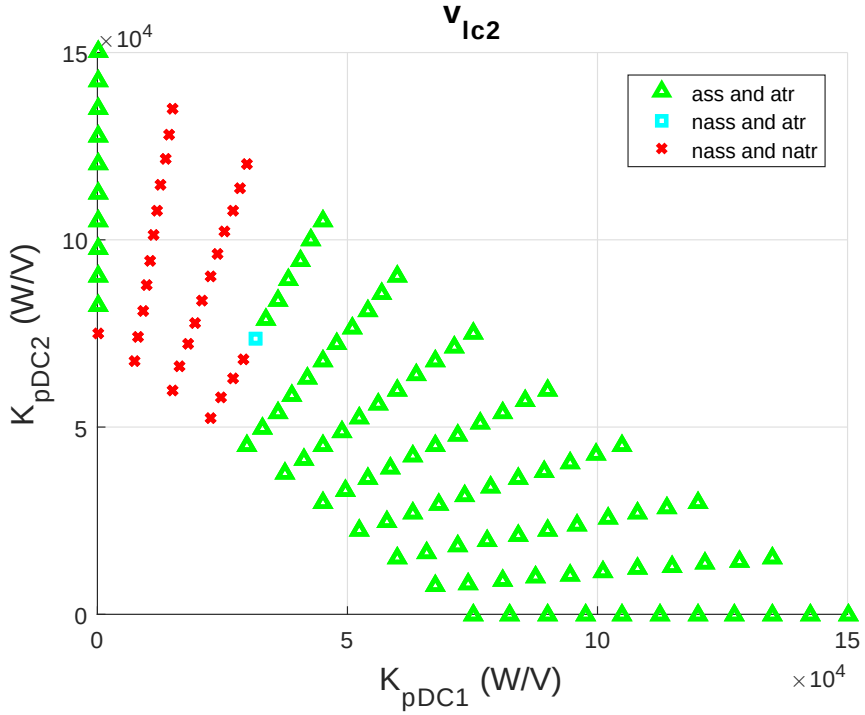

Figure B.158: Admissibility graph of voltage v_{lc2} from simulation 8 of Case 2

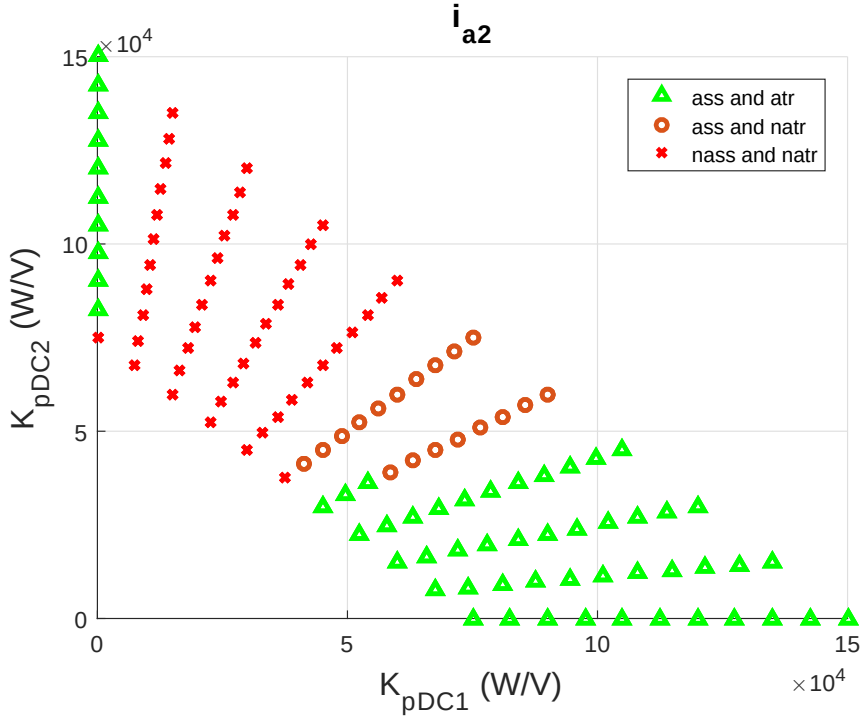

Figure B.159: Admissibility graph of current i_{a2} from simulation 8 of Case 2

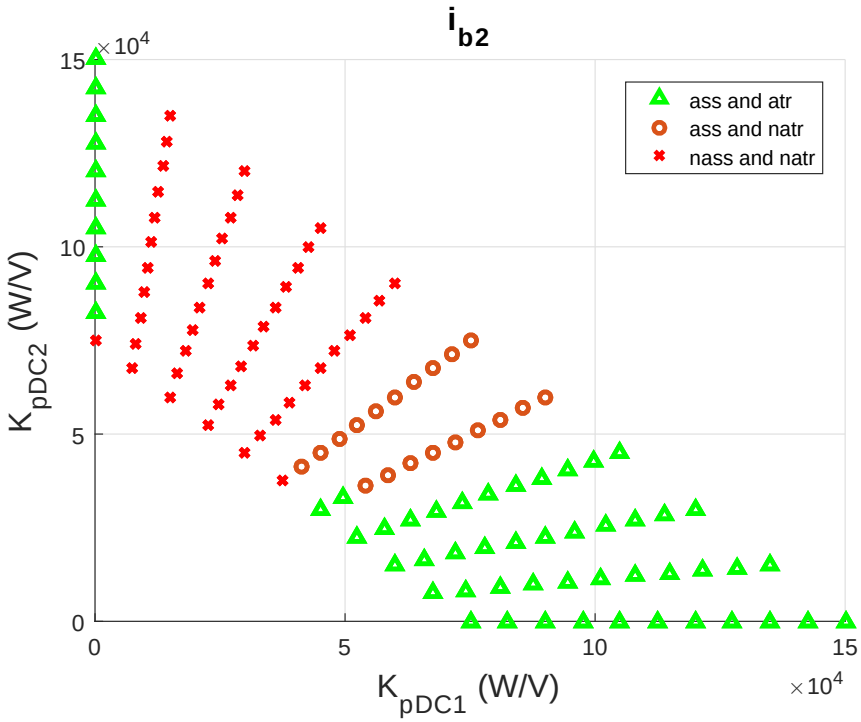

Figure B.160: Admissibility graph of current i_{b2} from simulation 8 of Case 2

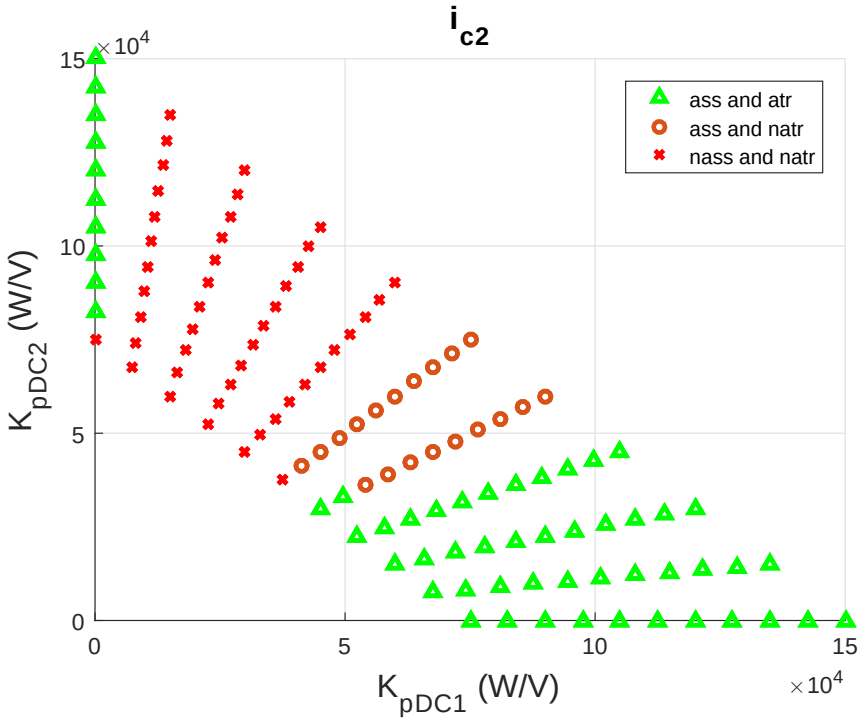

Figure B.161: Admissibility graph of current i_{c2} from simulation 8 of Case 2

B.9 Simulation 9

Simulation 9: $K_{pDC} \in [11000, 70000]$ with a step of 5900. The parameter α is varied between 0 and 1 with a step of 0.05. In total 231 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.9.1 Voltages and currents of the multi-terminal HVDC grid

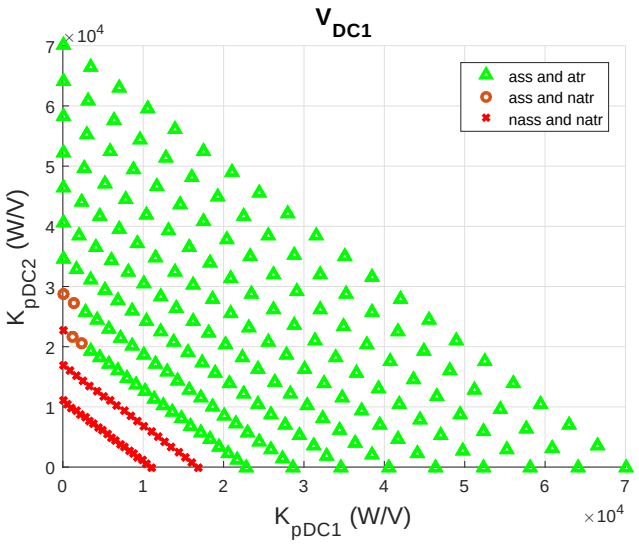

Figure B.162: Admissibility graph of voltage V_{DC1} from simulation 9 of Case 2

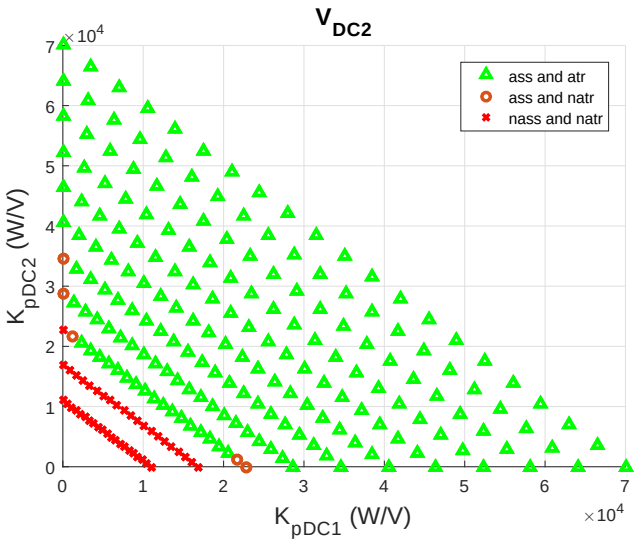

Figure B.163: Admissibility graph of voltage V_{DC2} from simulation 9 of Case 2

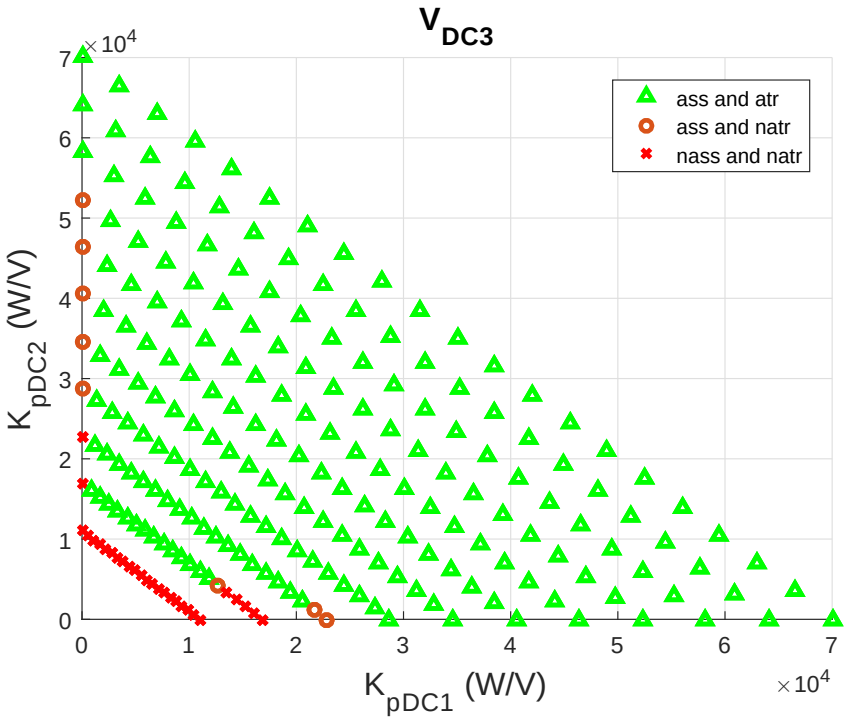

Figure B.164: Admissibility graph of voltage V_{DC3} from simulation 9 of Case 2

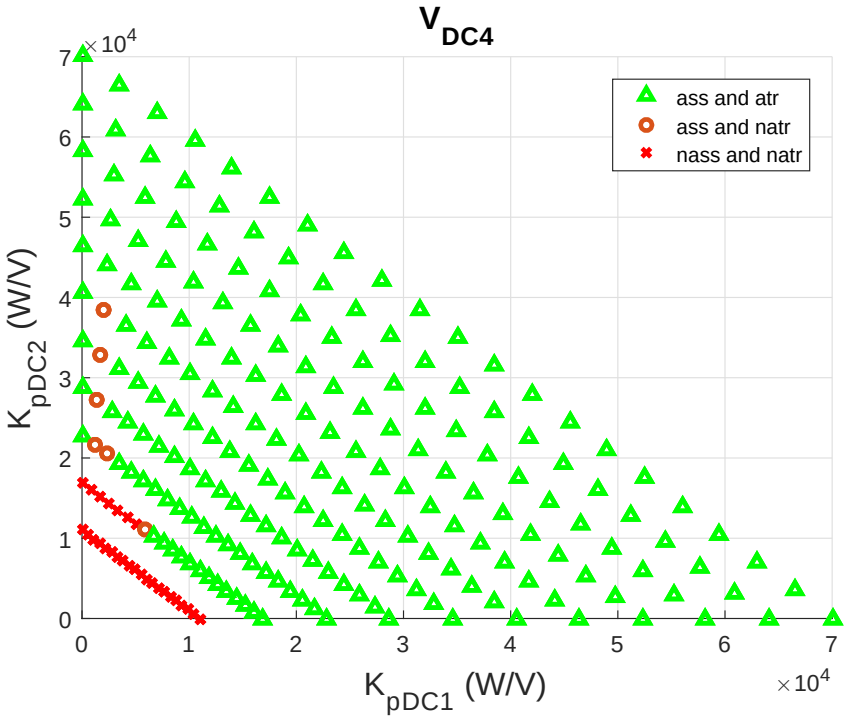

Figure B.165: Admissibility graph of voltage V_{DC4} from simulation 9 of Case 2

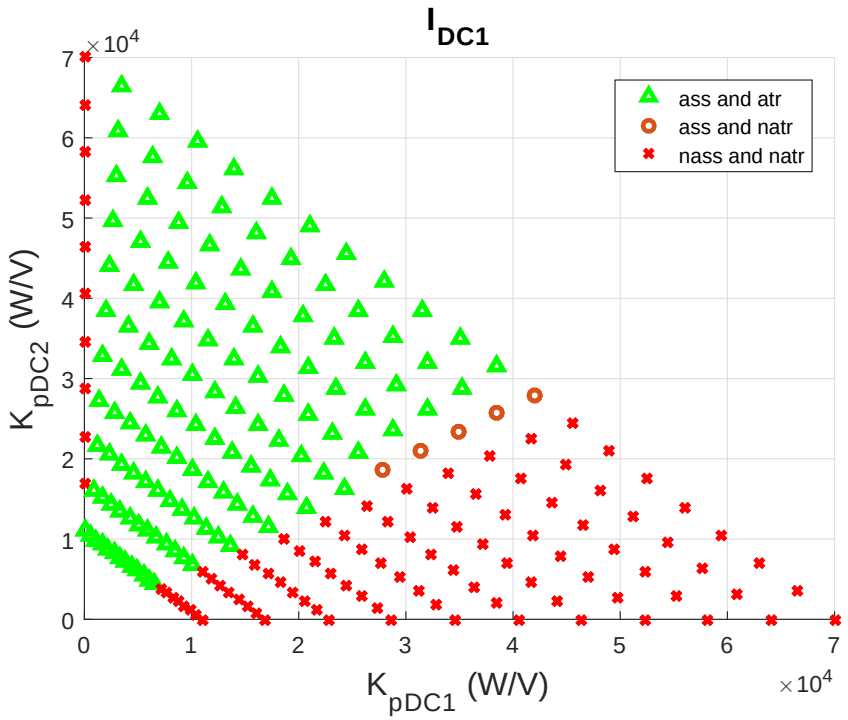

Figure B.166: Admissibility graph of current I_{DC1} from simulation 9 of Case 2

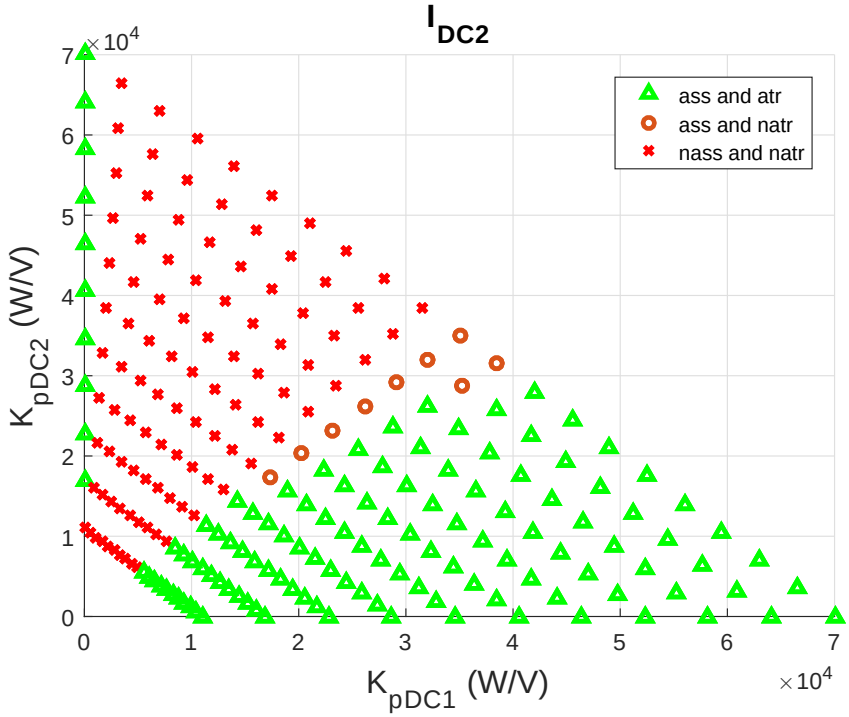

Figure B.167: Admissibility graph of current I_{DC2} from simulation 9 of Case 2

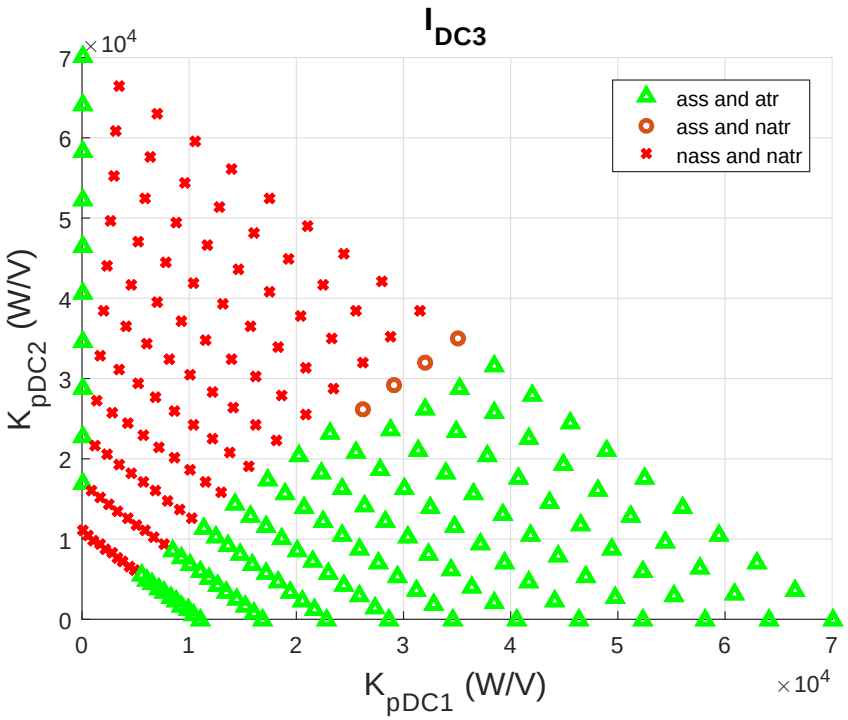

Figure B.168: Admissibility graph of current I_{DC3} from simulation 9 of Case 2

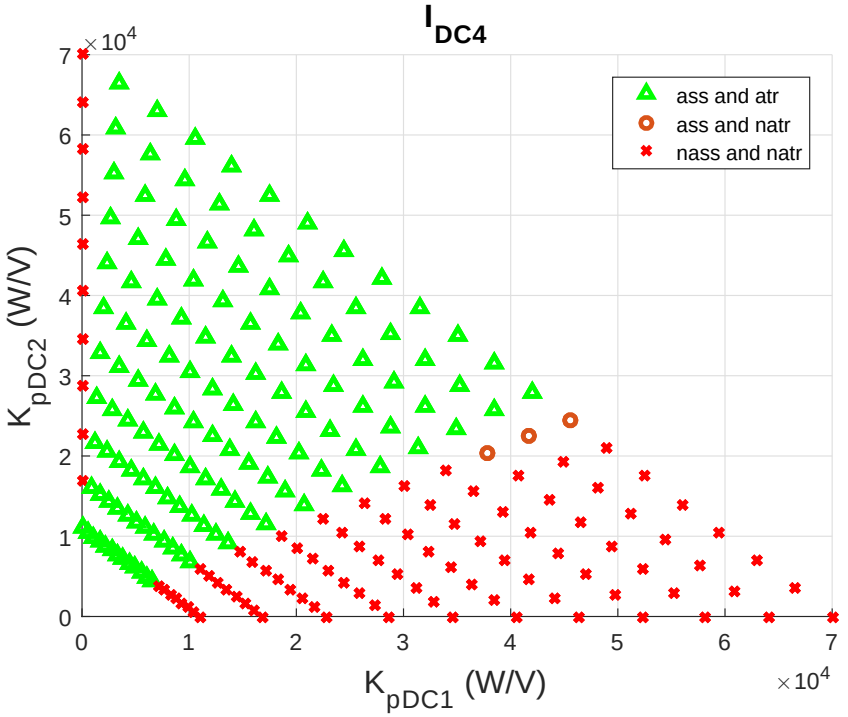

Figure B.169: Admissibility graph of current I_{DC4} from simulation 9 of Case 2

B.9.2 Voltages and currents of power converter 1

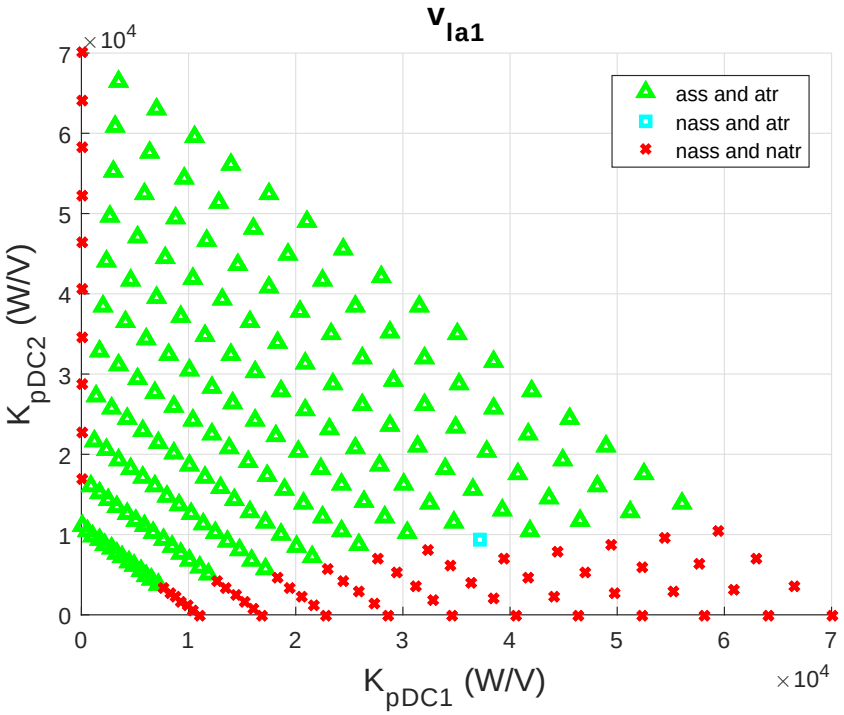

Figure B.170: Admissibility graph of voltage v_{la1} from simulation 9 of Case 2

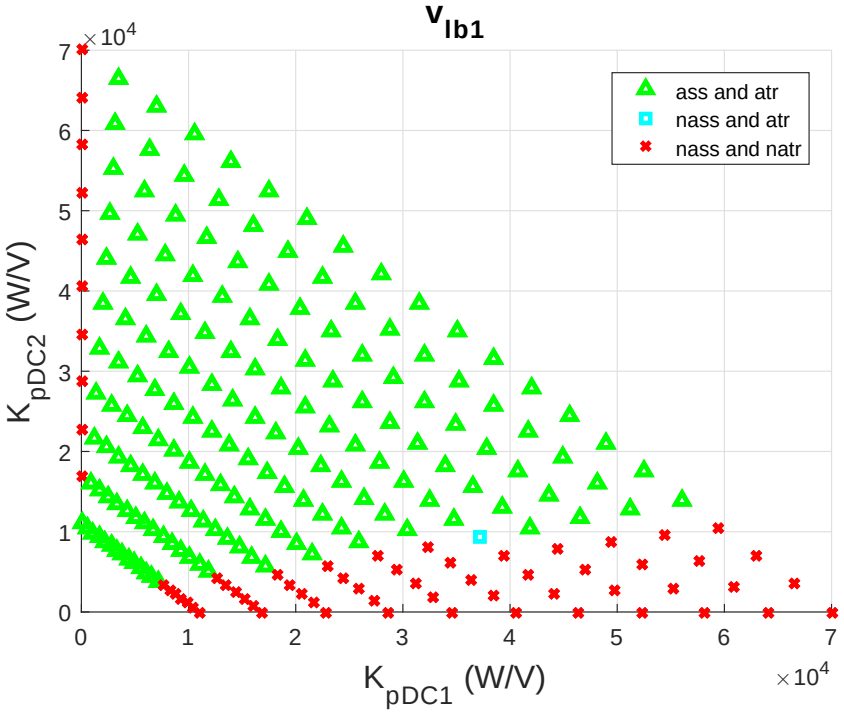

Figure B.171: Admissibility graph of voltage v_{lb1} from simulation 9 of Case 2

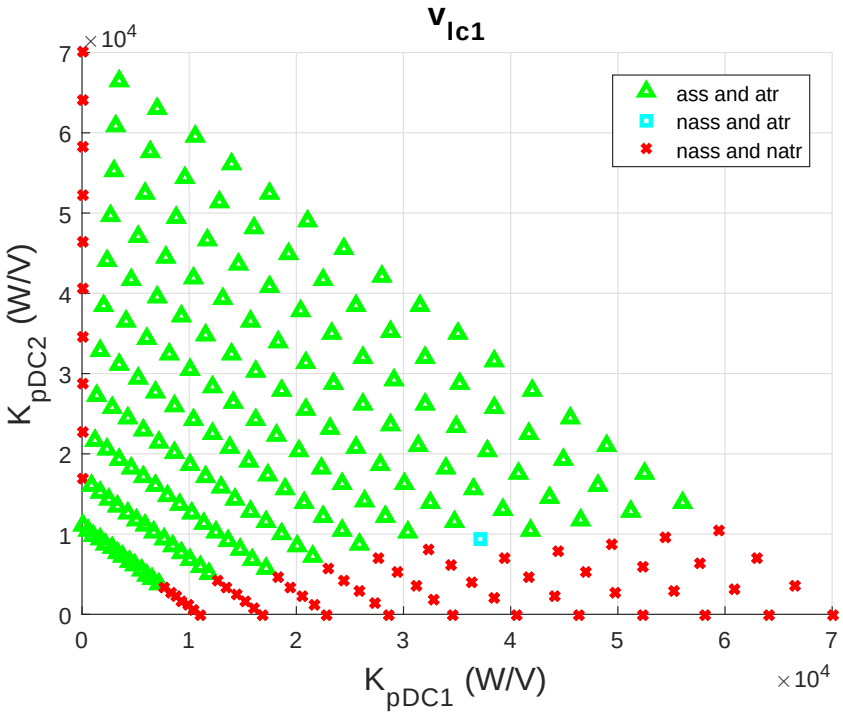

Figure B.172: Admissibility graph of voltage v_{lc1} from simulation 9 of Case 2

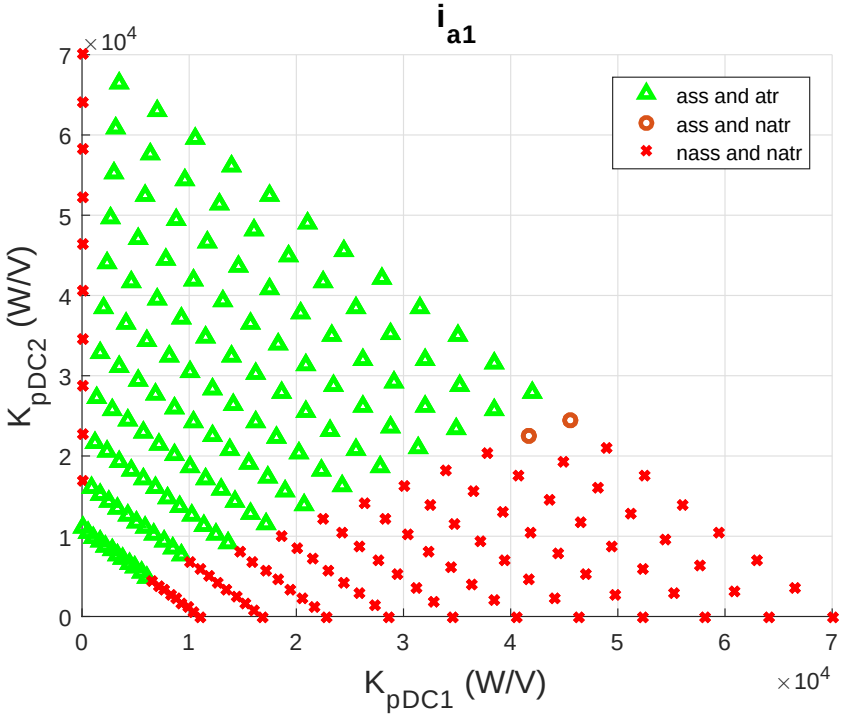

Figure B.173: Admissibility graph of current i_{a1} from simulation 9 of Case 2

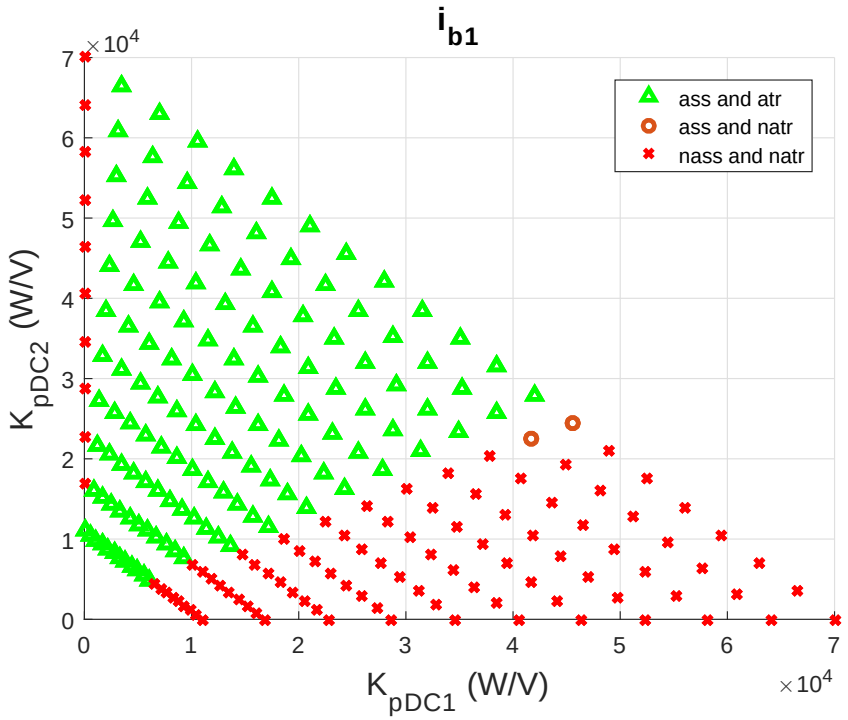

Figure B.174: Admissibility graph of current i_{b1} from simulation 9 of Case 2

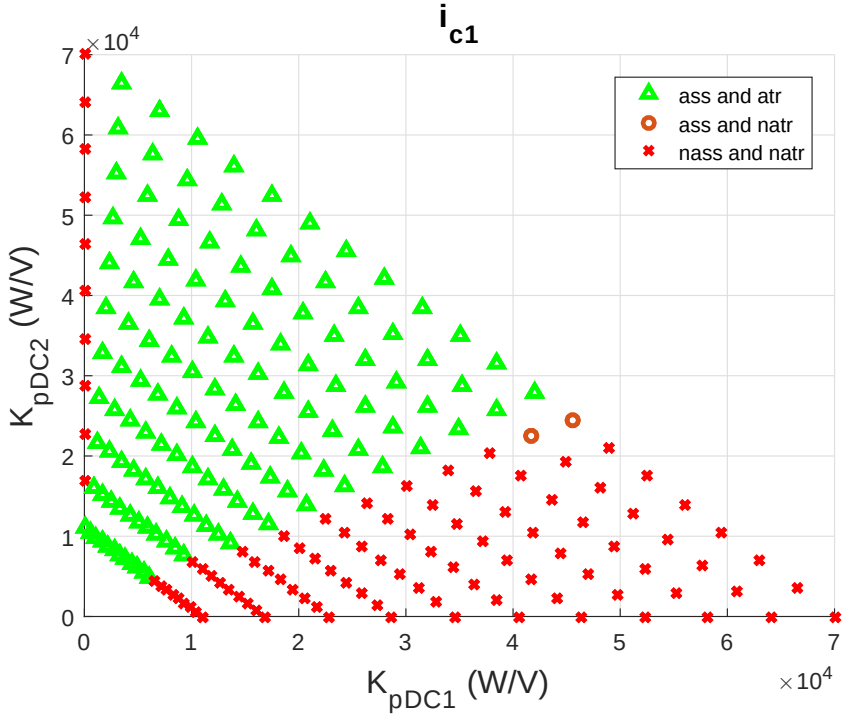

Figure B.175: Admissibility graph of current i_{c1} from simulation 9 of Case 2

B.9.3 Voltages and currents of power converter 2

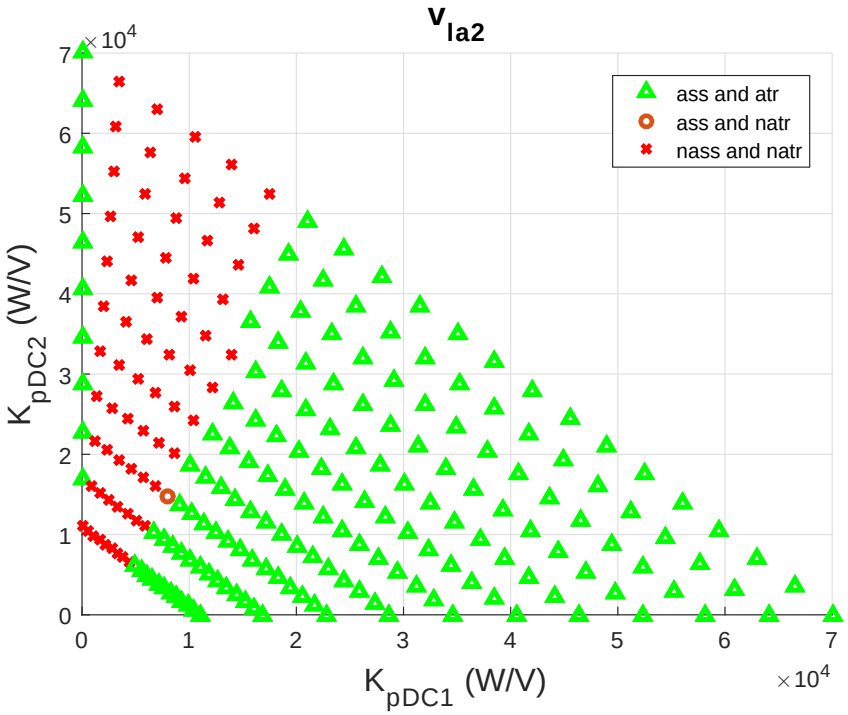

Figure B.176: Admissibility graph of voltage v_{la2} from simulation 9 of Case 2

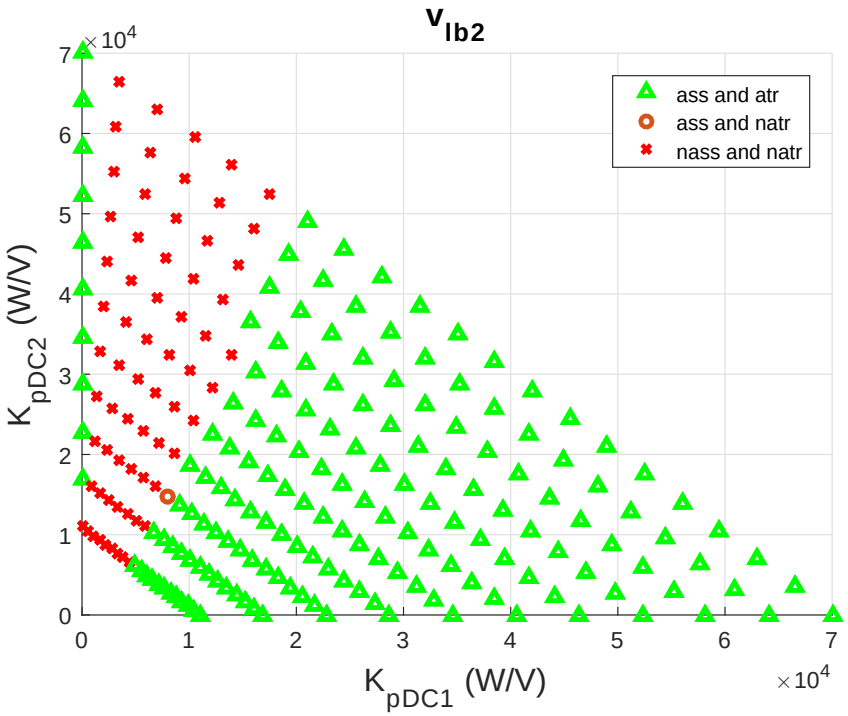

Figure B.177: Admissibility graph of voltage v_{lb2} from simulation 9 of Case 2

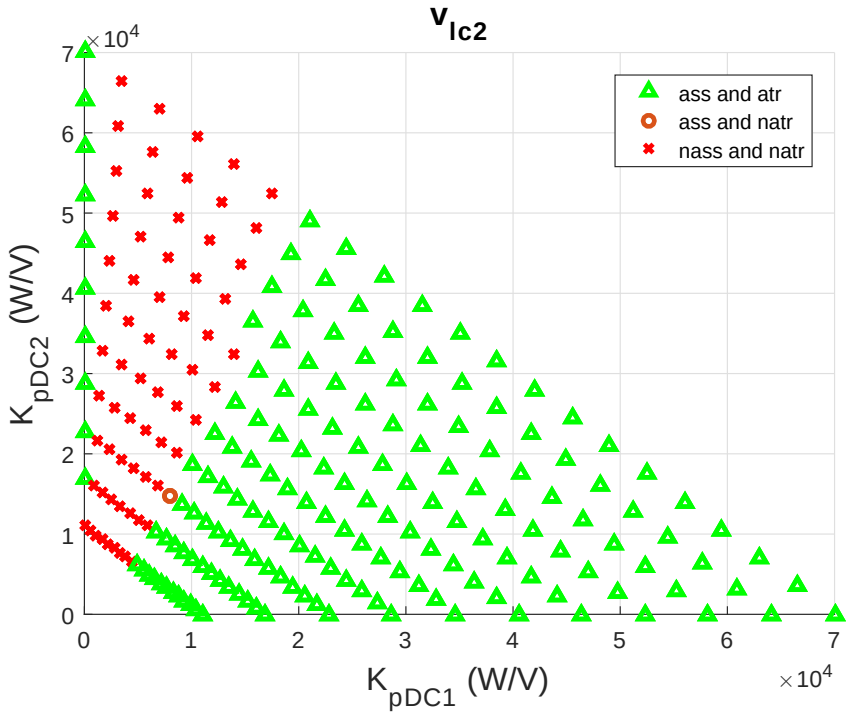

Figure B.178: Admissibility graph of voltage v_{lc2} from simulation 9 of Case 2

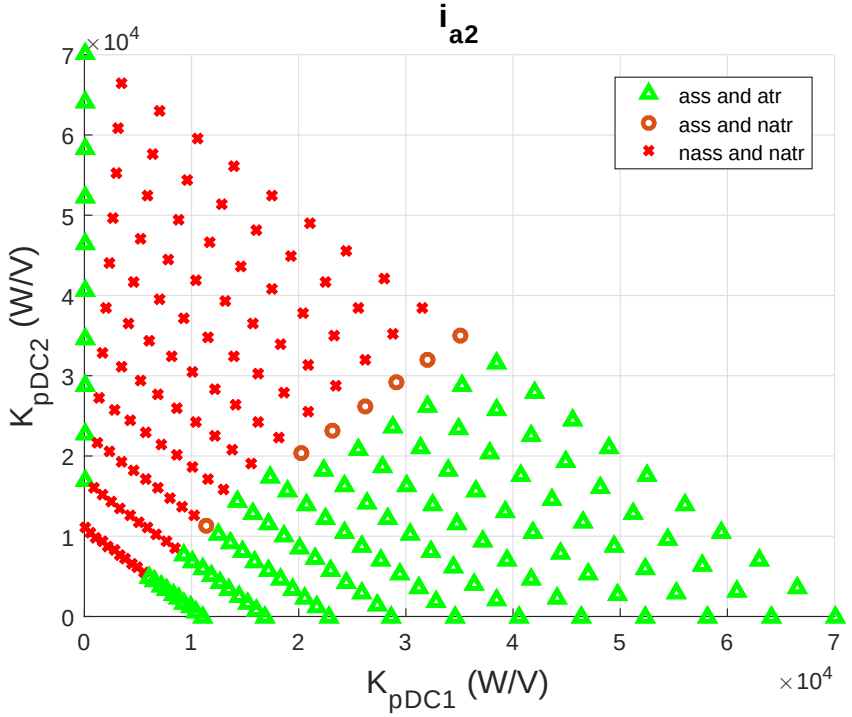

Figure B.179: Admissibility graph of current i_{a2} from simulation 9 of Case 2

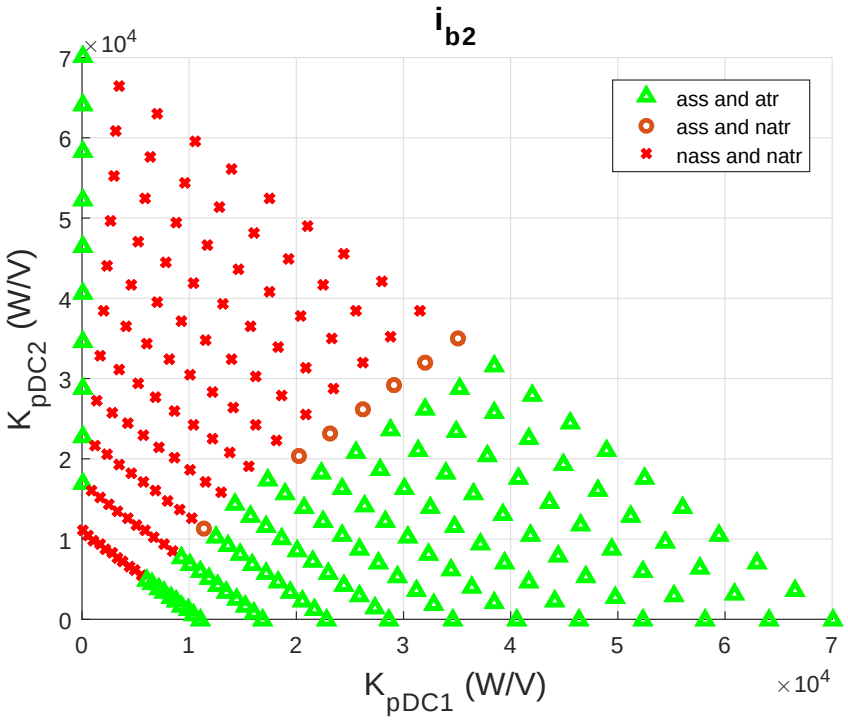

Figure B.180: Admissibility graph of current i_{b2} from simulation 9 of Case 2

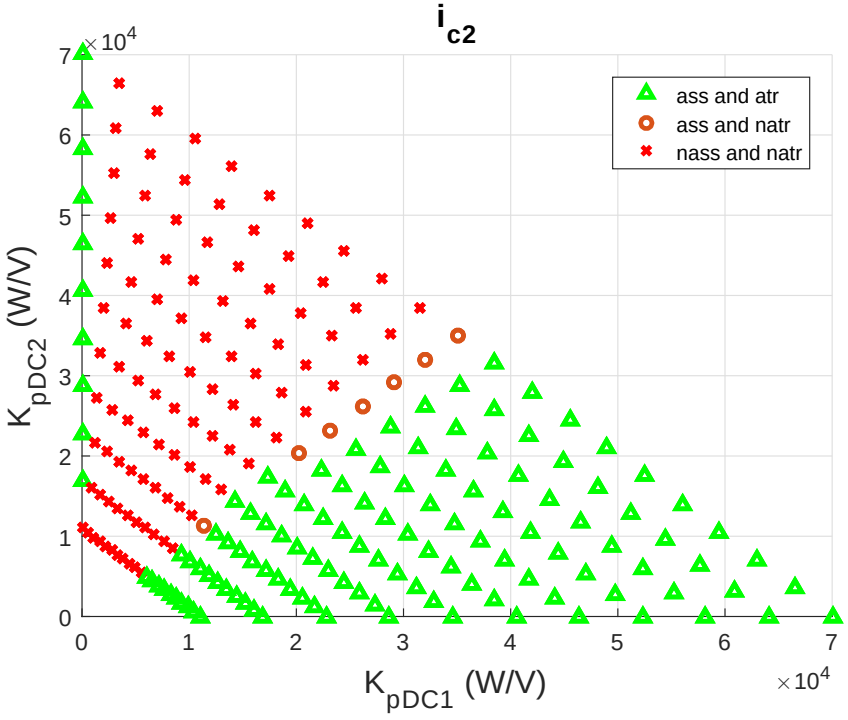

Figure B.181: Admissibility graph of current i_{c2} from simulation 9 of Case 2

B.10 Simulation 10

Simulation 10: $K_{pDC2} \in [10368.42, 27368.42]$ with a step of 1700 and $K_{pDC1} \in [12200, 31200]$ with a step of 1900. In total 11 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.10.1 Voltages and currents of the multi-terminal HVDC grid

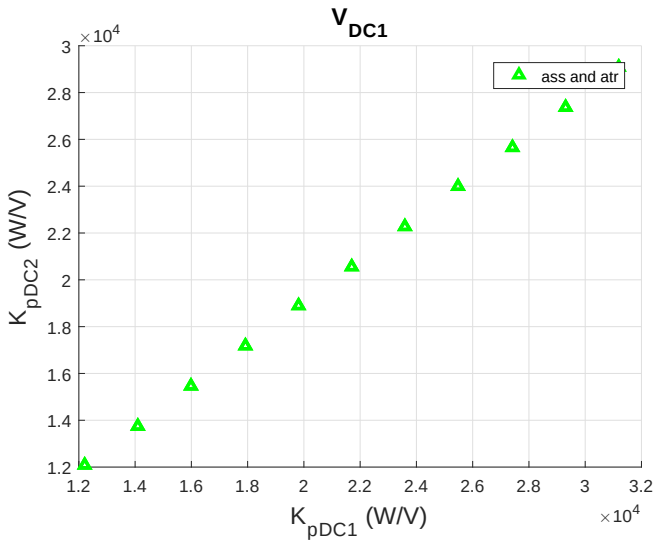

Figure B.182: Admissibility graph of voltage V_{DC1} from simulation 10 of Case 2

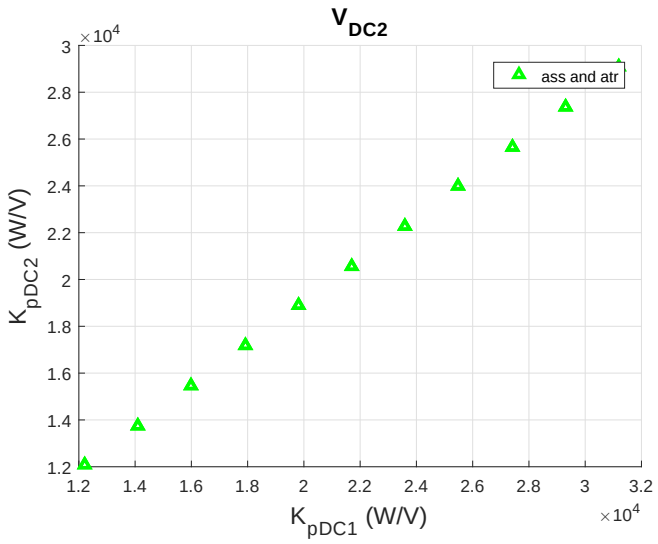

Figure B.183: Admissibility graph of voltage V_{DC2} from simulation 10 of Case 2

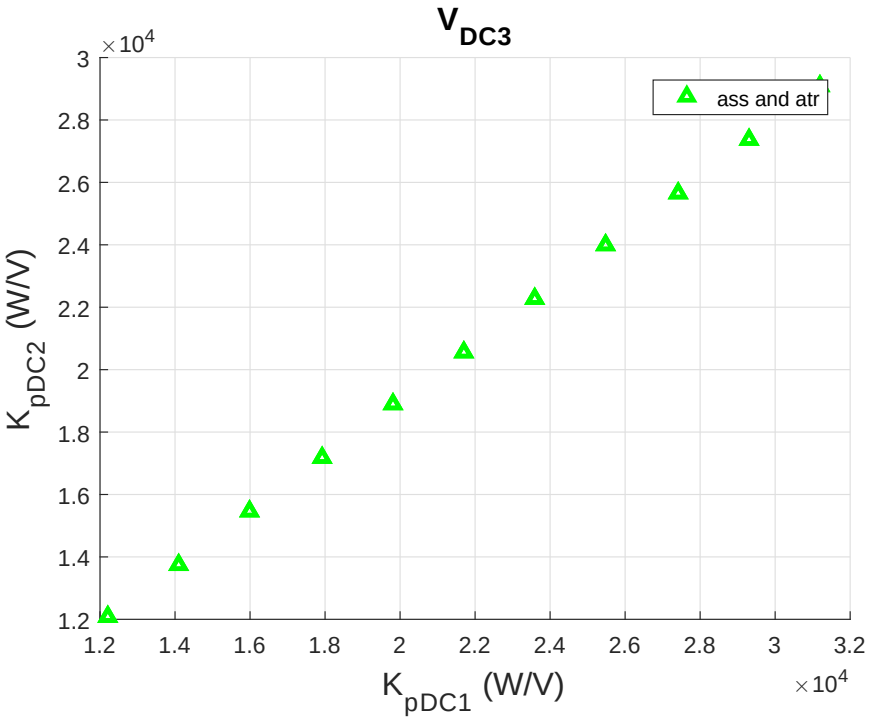

Figure B.184: Admissibility graph of voltage V_{DC3} from simulation 10 of Case 2

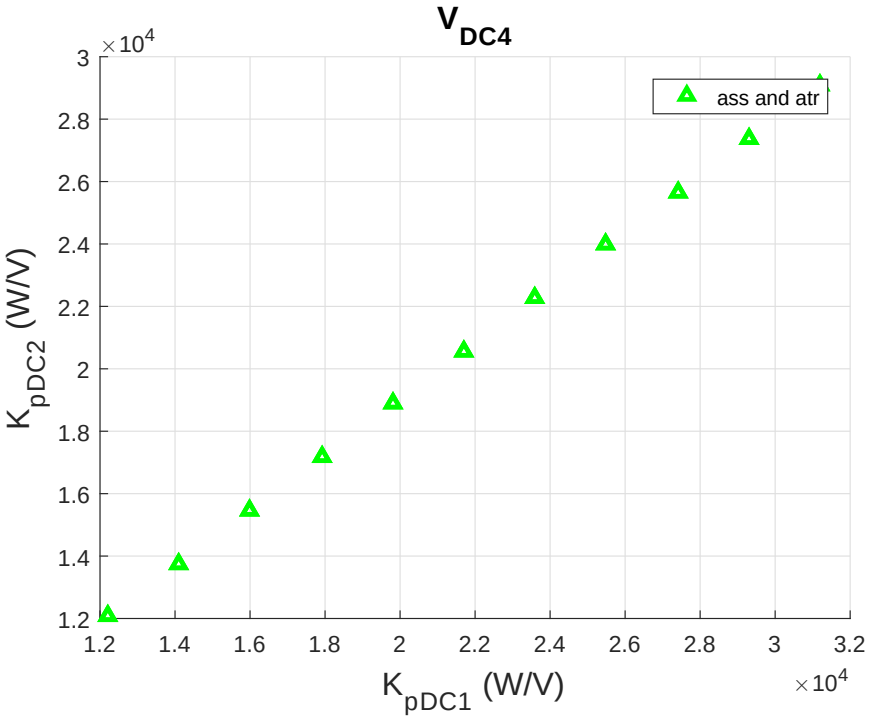

Figure B.185: Admissibility graph of voltage V_{DC4} from simulation 10 of Case 2

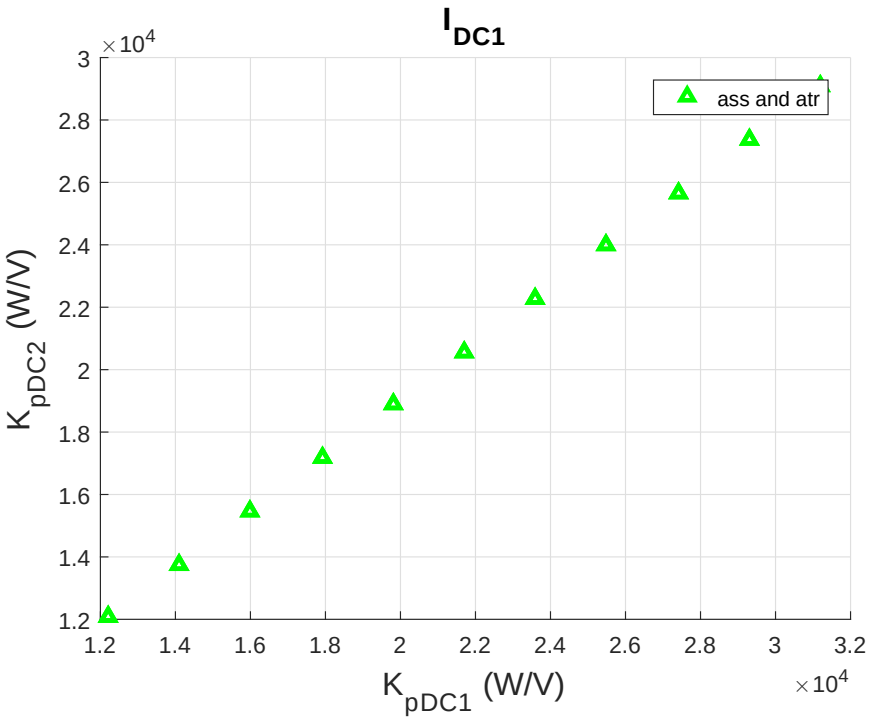

Figure B.186: Admissibility graph of current I_{DC1} from simulation 10 of Case 2

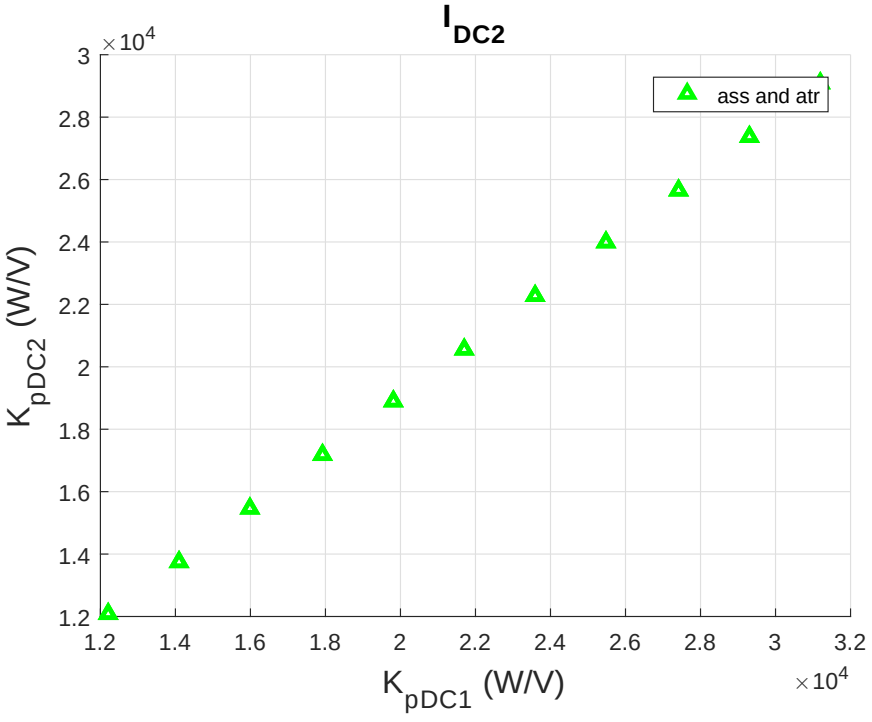

Figure B.187: Admissibility graph of current I_{DC2} from simulation 10 of Case 2

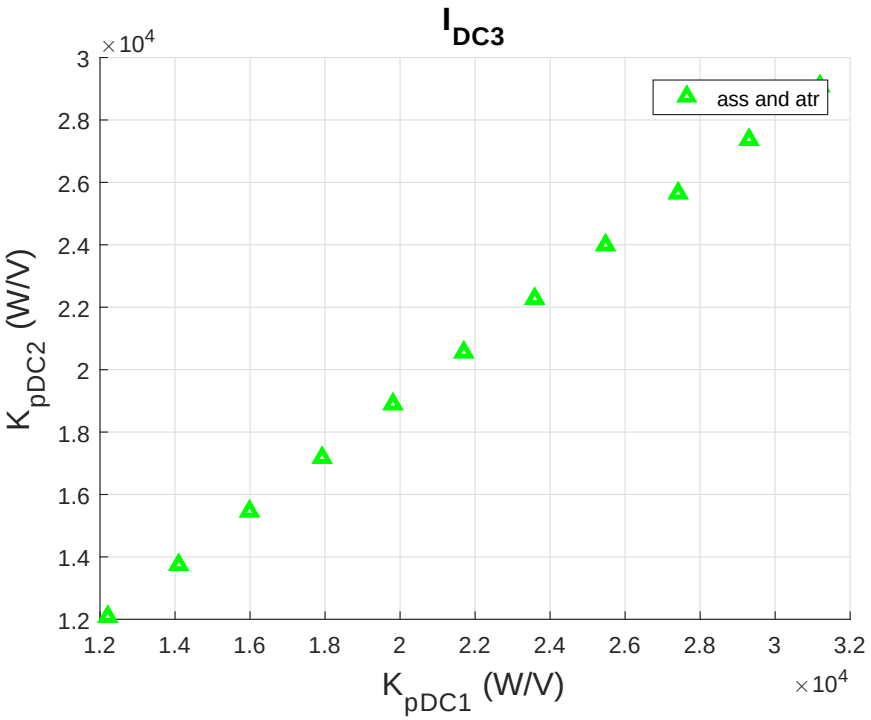

Figure B.188: Admissibility graph of current I_{DC3} from simulation 10 of Case 2

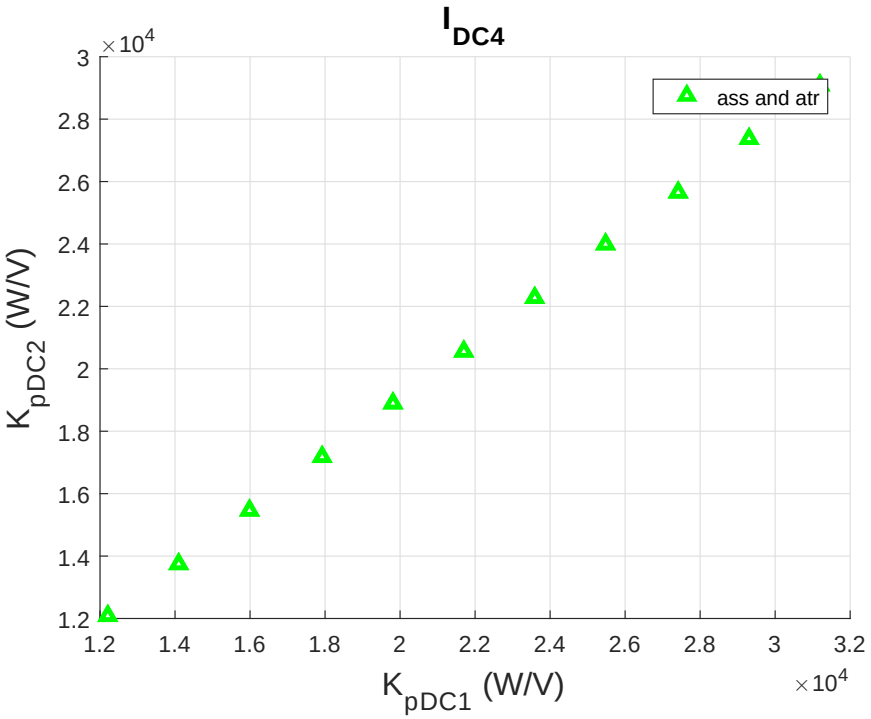

Figure B.189: Admissibility graph of current I_{DC4} from simulation 10 of Case 2

B.10.2 Voltages and currents of power converter 1

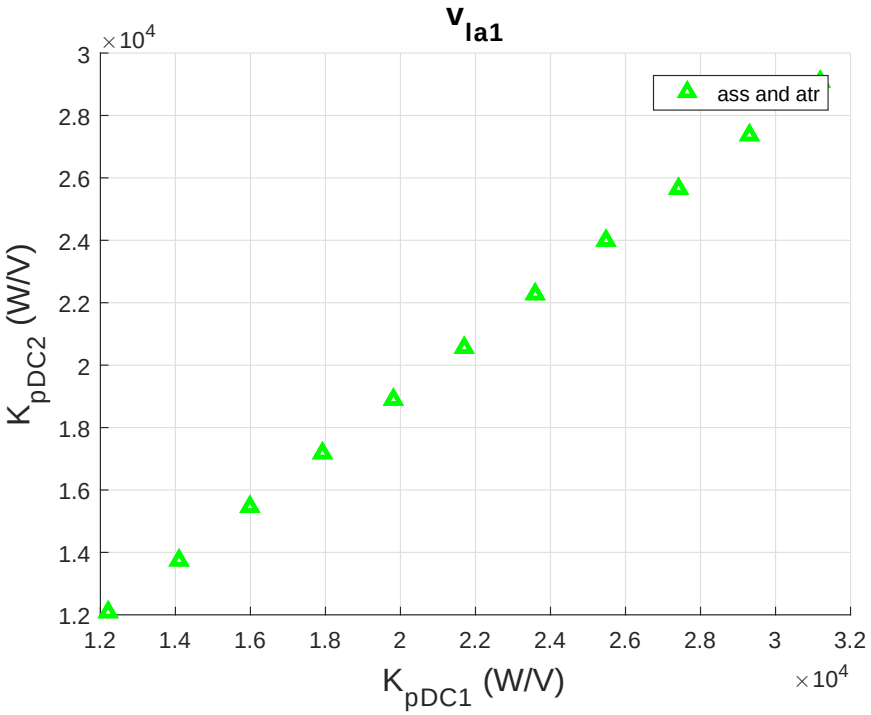

Figure B.190: Admissibility graph of voltage v_{la1} from simulation 10 of Case 2

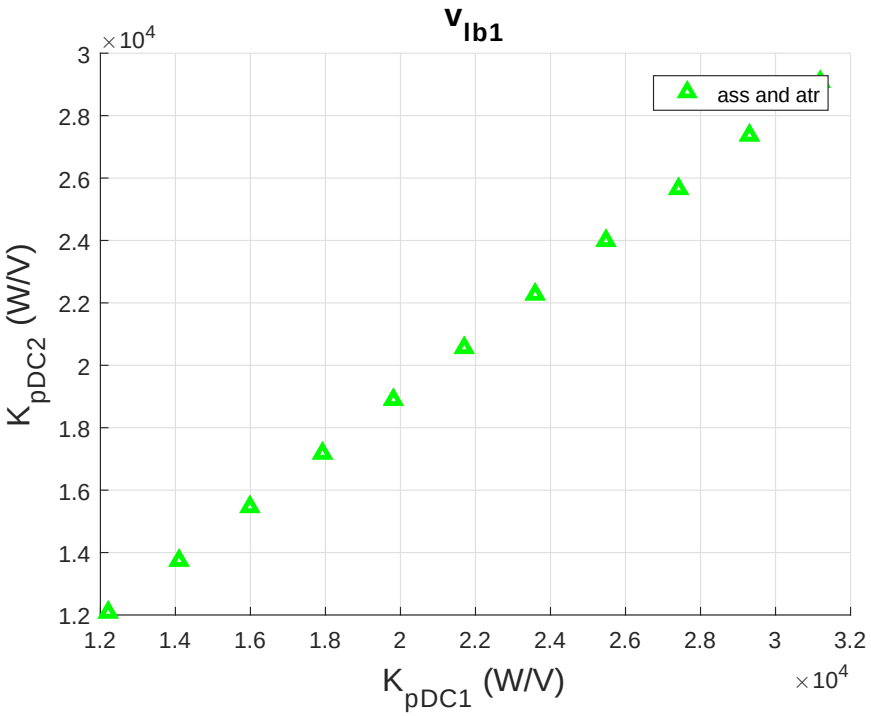

Figure B.191: Admissibility graph of voltage v_{lb1} from simulation 10 of Case 2

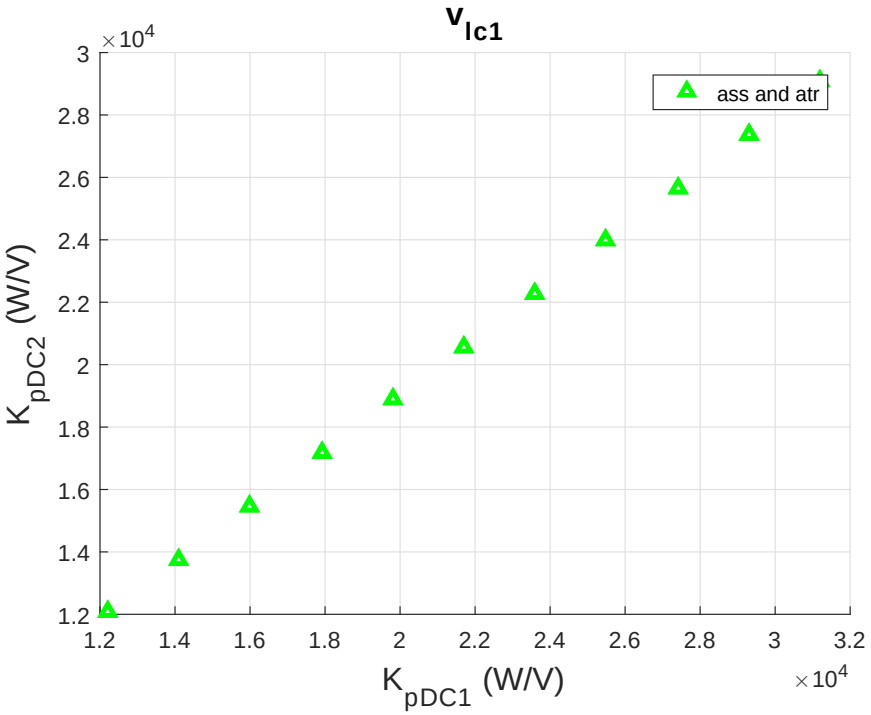

Figure B.192: Admissibility graph of voltage v_{lc1} from simulation 10 of Case 2

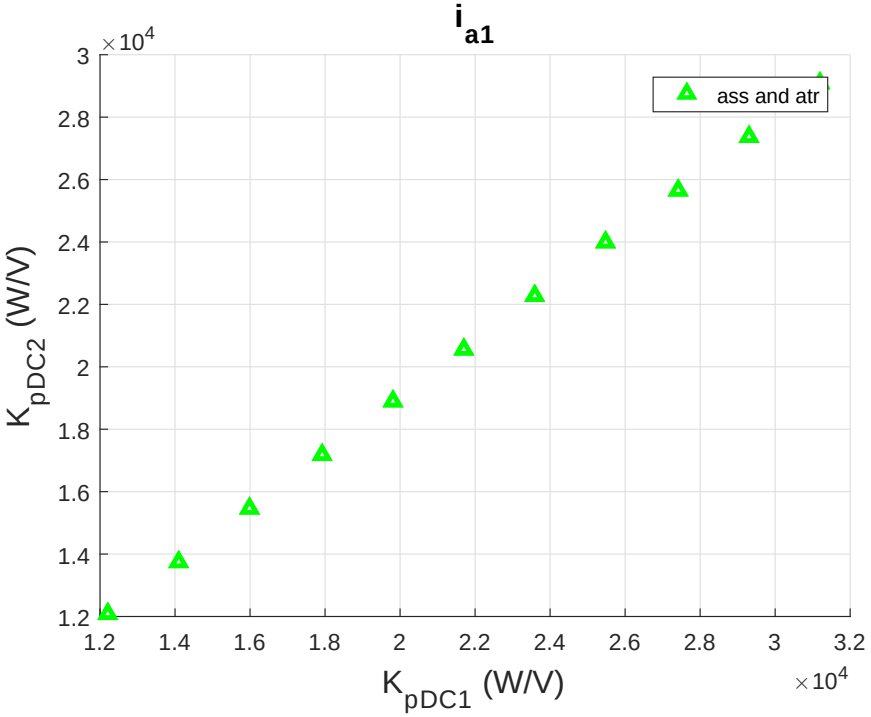

Figure B.193: Admissibility graph of current i_{a1} from simulation 10 of Case 2

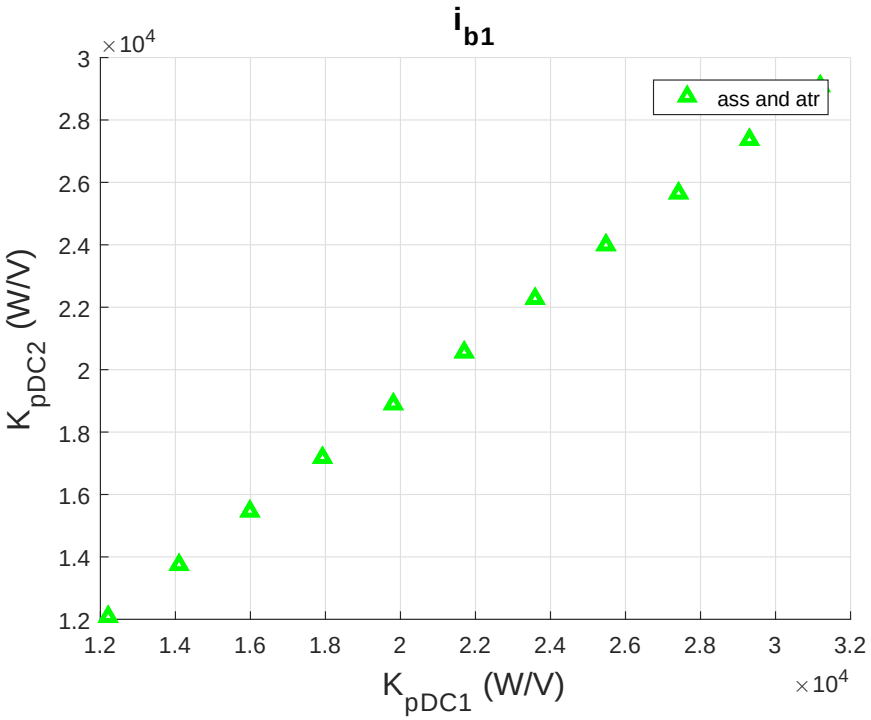

Figure B.194: Admissibility graph of current i_{b1} from simulation 10 of Case 2

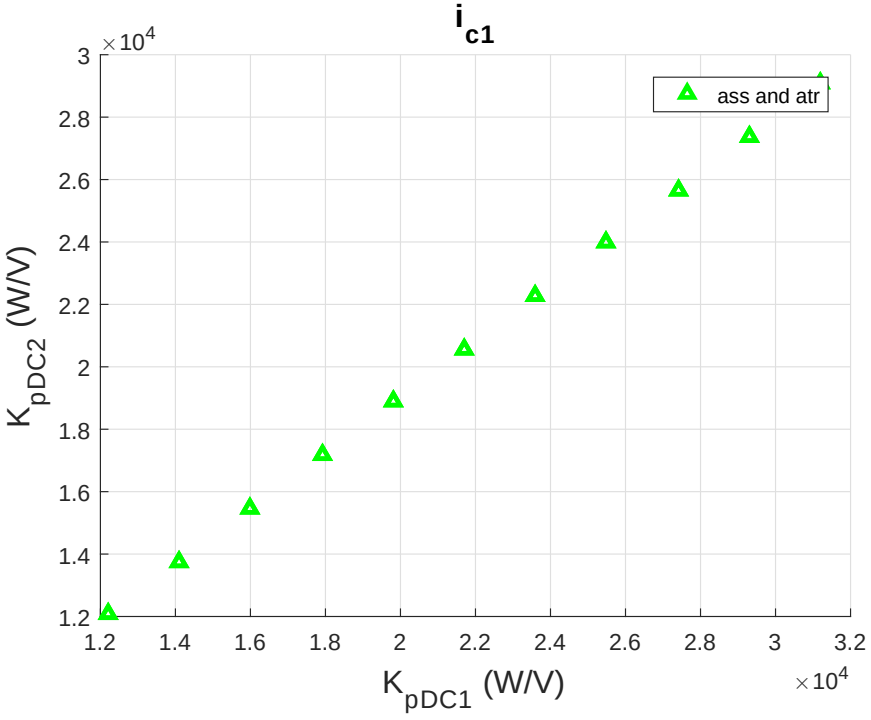

Figure B.195: Admissibility graph of current i_{c1} from simulation 10 of Case 2

B.10.3 Voltages and currents of power converter 2

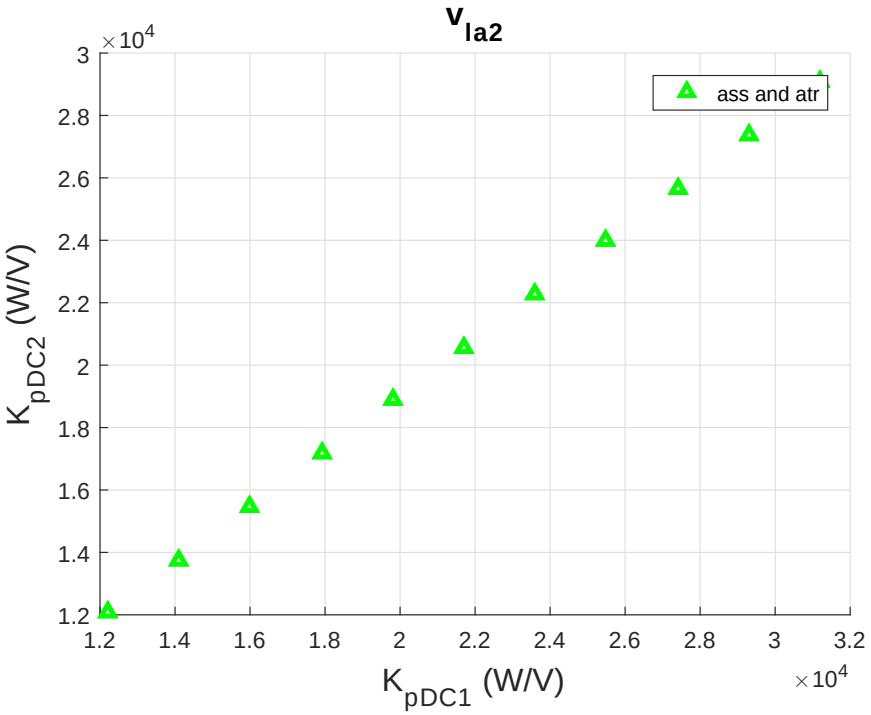

Figure B.196: Admissibility graph of voltage v_{la2} from simulation 10 of Case 2

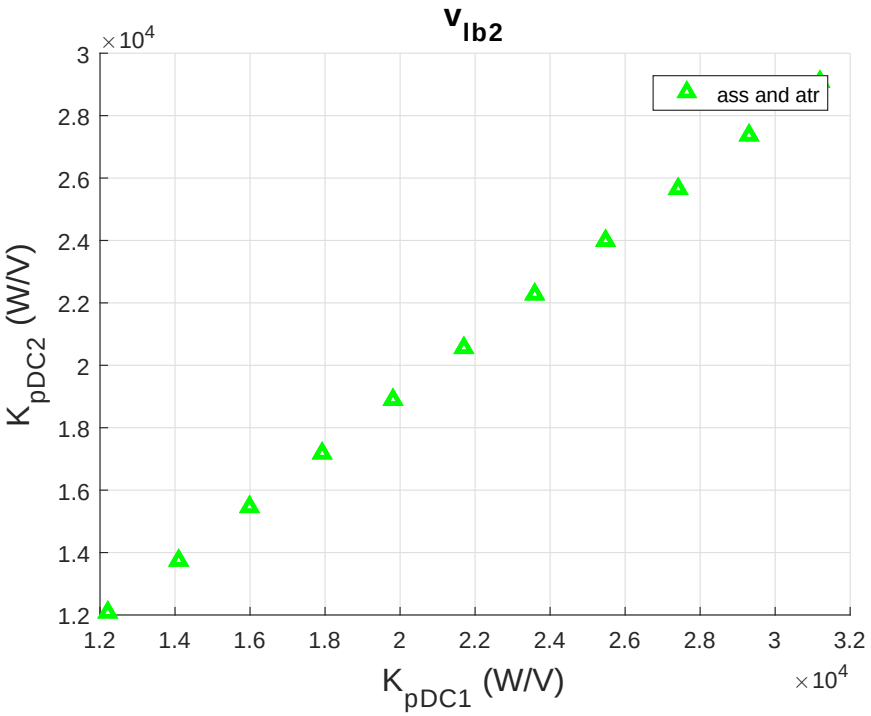

Figure B.197: Admissibility graph of voltage v_{lb2} from simulation 10 of Case 2

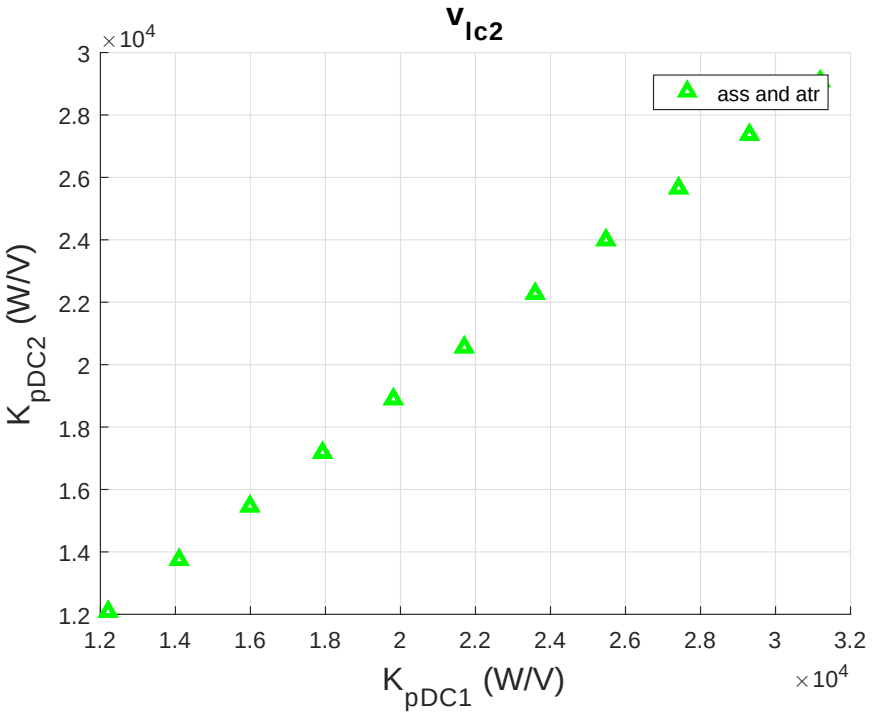

Figure B.198: Admissibility graph of voltage v_{lc2} from simulation 10 of Case 2

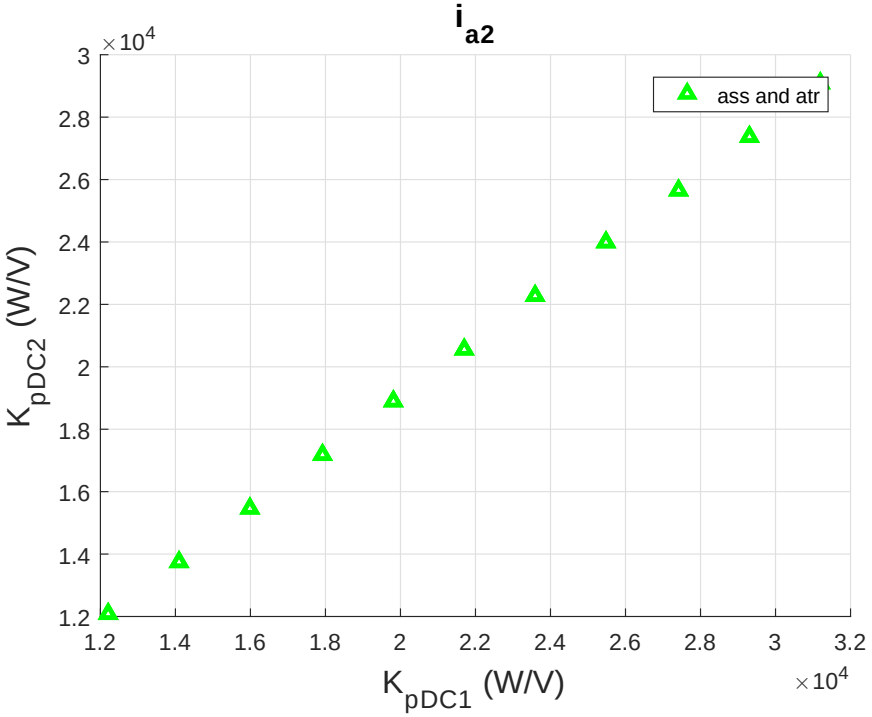

Figure B.199: Admissibility graph of current i_{a2} from simulation 10 of Case 2

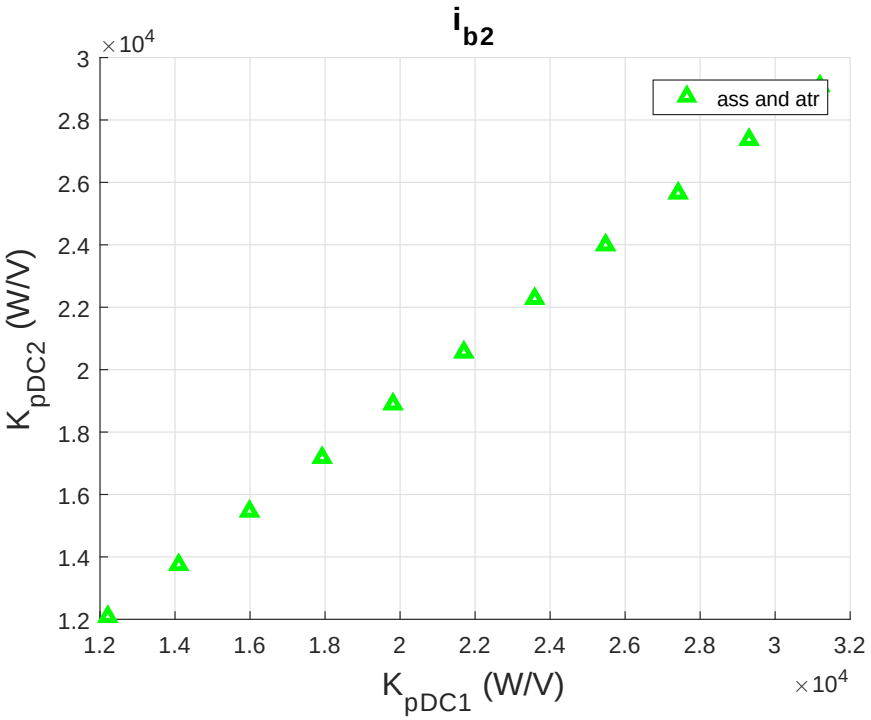

Figure B.200: Admissibility graph of current i_{b2} from simulation 10 of Case 2

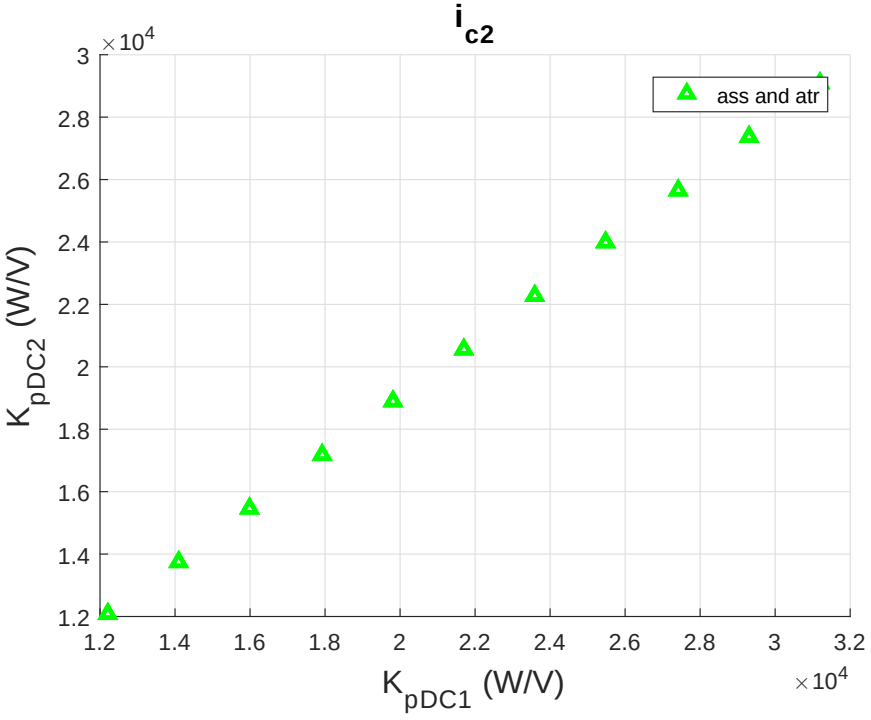

Figure B.201: Admissibility graph of current i_{c2} from simulation 10 of Case 2

B.11 Simulation 11

Simulation 11: $K_{pDC} \in [18000, 58000]$ with a step of 4000. Therefore, $K_{pDC2} \in [9000, 29000]$ and $K_{pDC1} \in [9000, 29000]$ with a step of 2000. In total 11 simulations for each electrical magnitude. The maximum admissible values are 10 % higher respect to the nominal values.

B.11.1 Voltages and currents of the multi-terminal HVDC grid

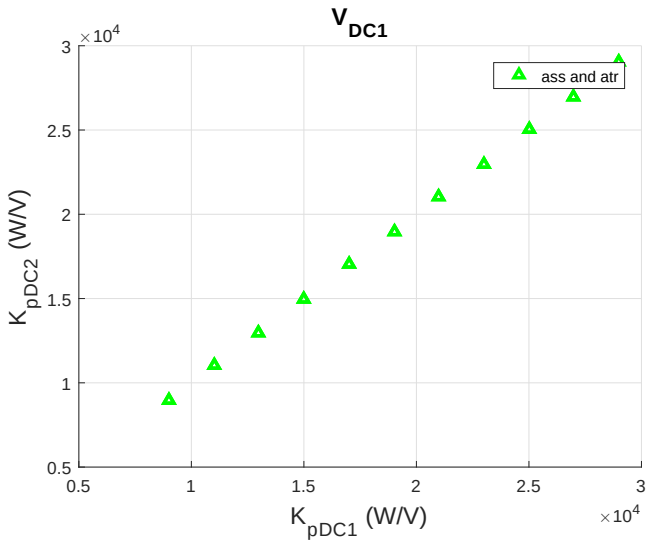

Figure B.202: Admissibility graph of voltage V_{DC1} from simulation 11 of Case 2

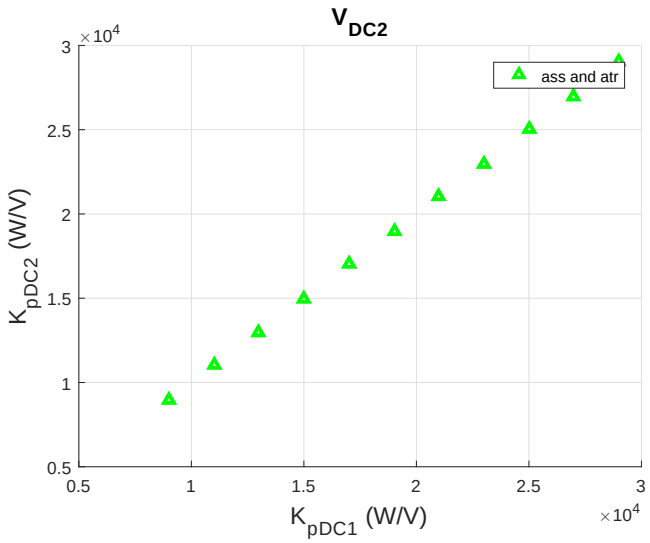

Figure B.203: Admissibility graph of voltage V_{DC2} from simulation 11 of Case 2

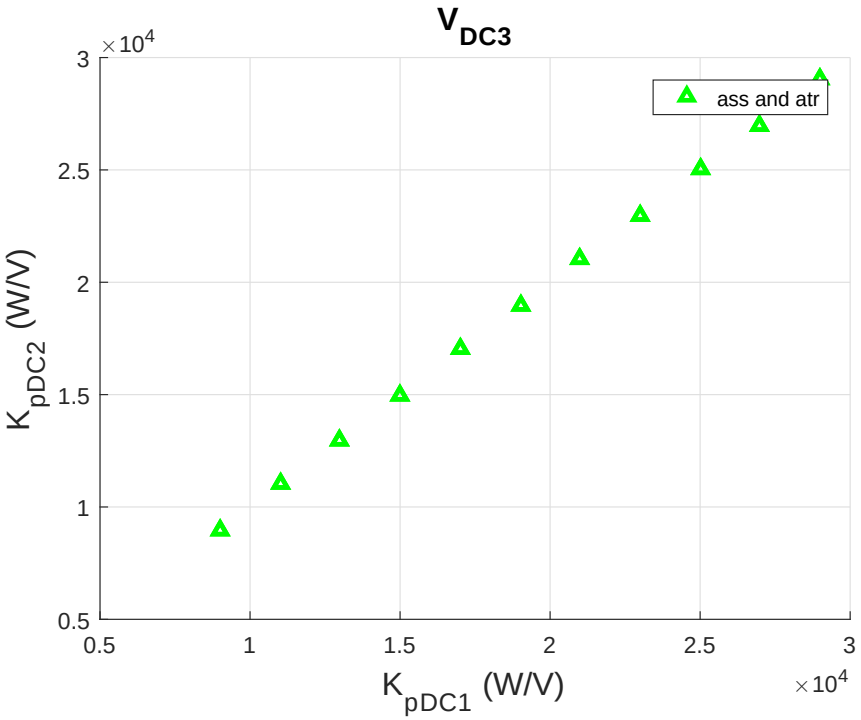

Figure B.204: Admissibility graph of voltage V_{DC3} from simulation 11 of Case 2

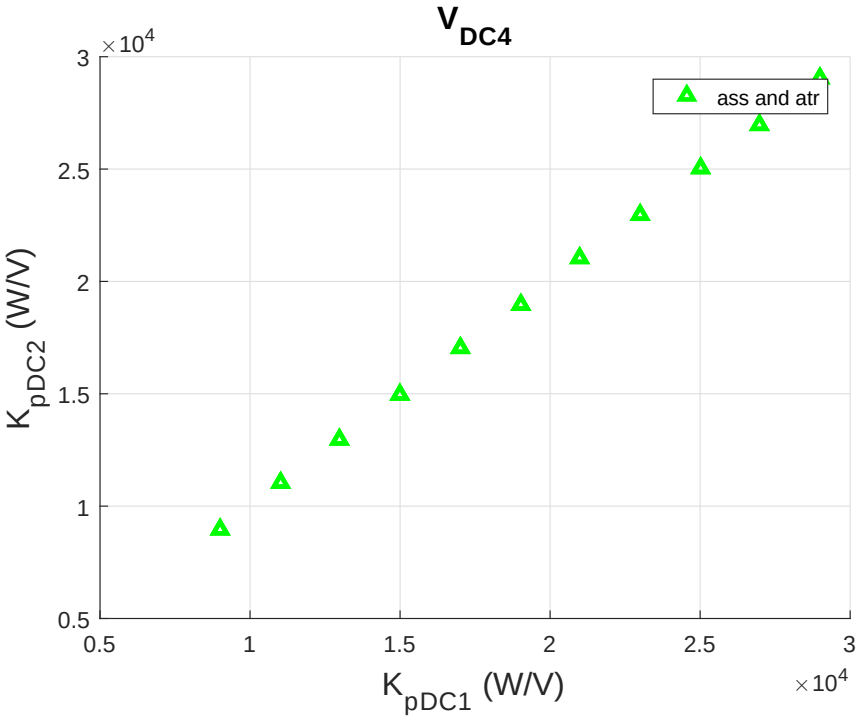

Figure B.205: Admissibility graph of voltage V_{DC4} from simulation 11 of Case 2

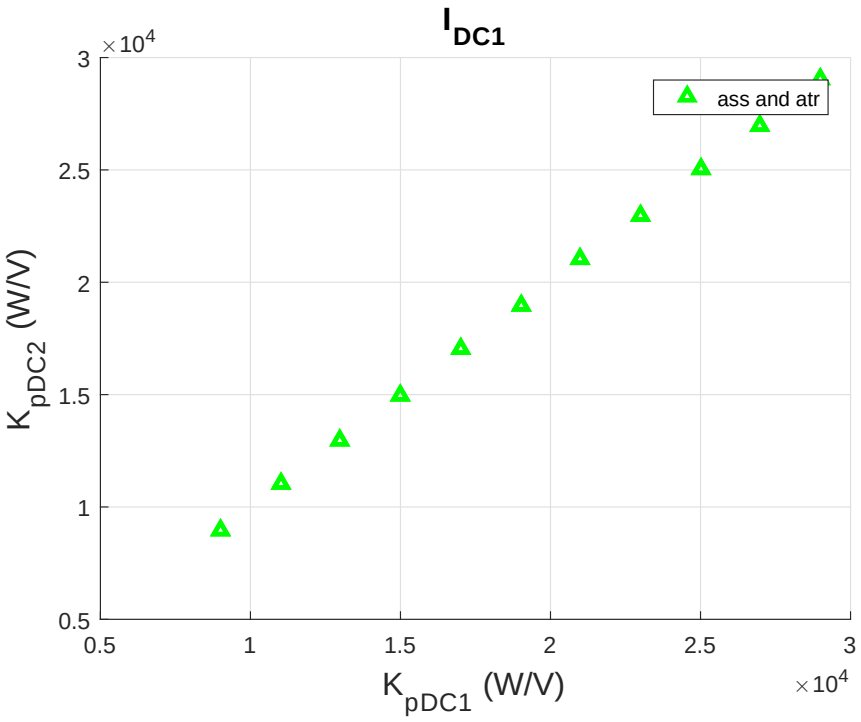

Figure B.206: Admissibility graph of current I_{DC1} from simulation 11 of Case 2

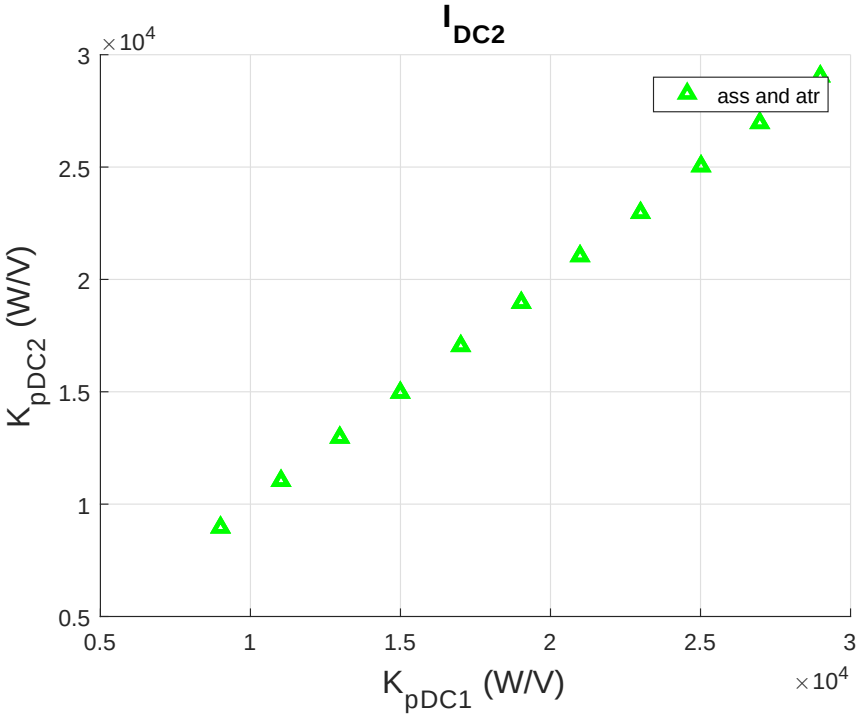

Figure B.207: Admissibility graph of current I_{DC2} from simulation 11 of Case 2

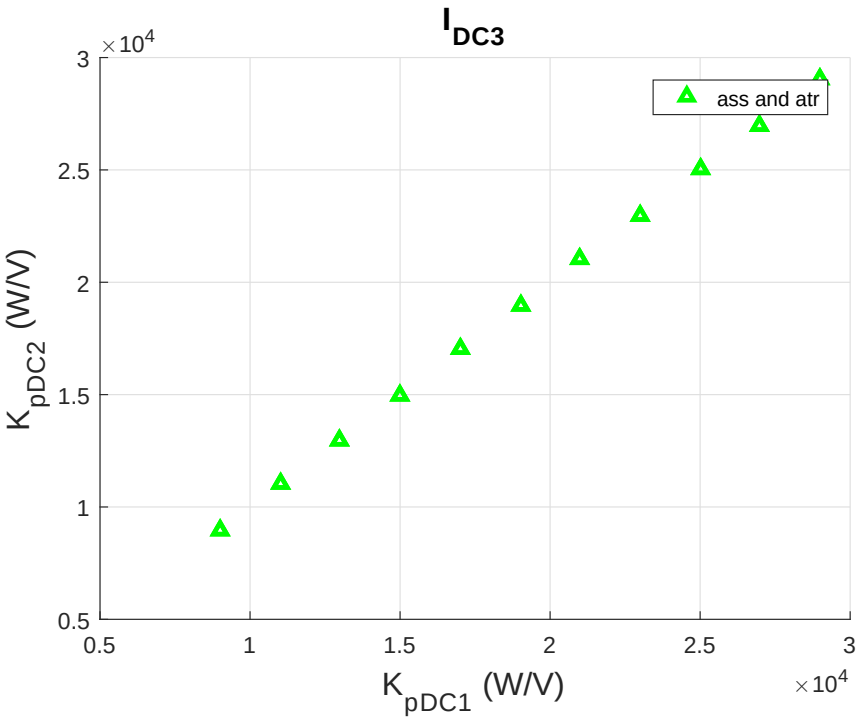

Figure B.208: Admissibility graph of current I_{DC3} from simulation 11 of Case 2

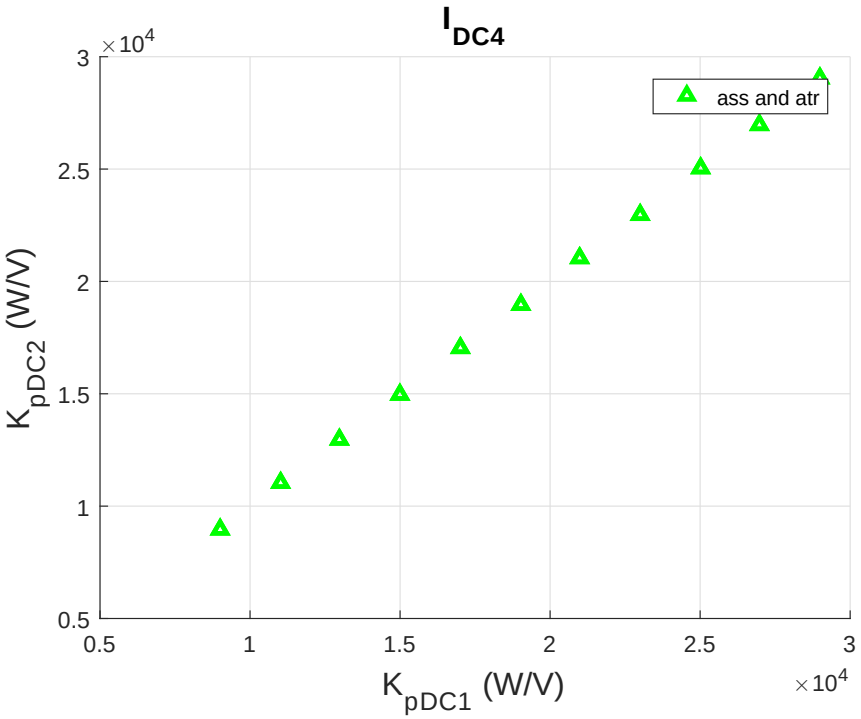

Figure B.209: Admissibility graph of current I_{DC4} from simulation 11 of Case 2

B.11.2 Voltages and currents of power converter 1

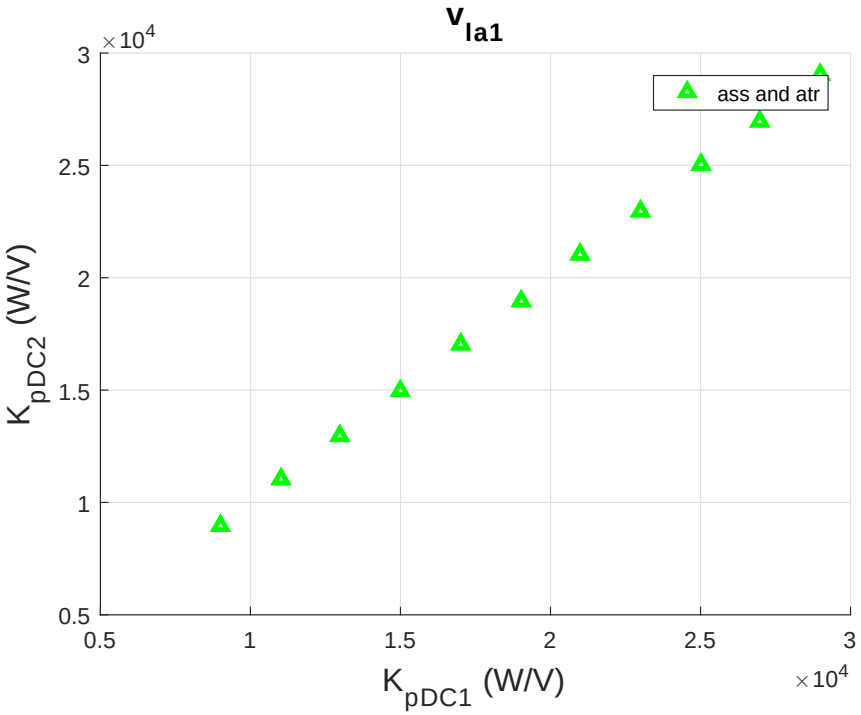

Figure B.210: Admissibility graph of voltage v_{la1} from simulation 11 of Case 2

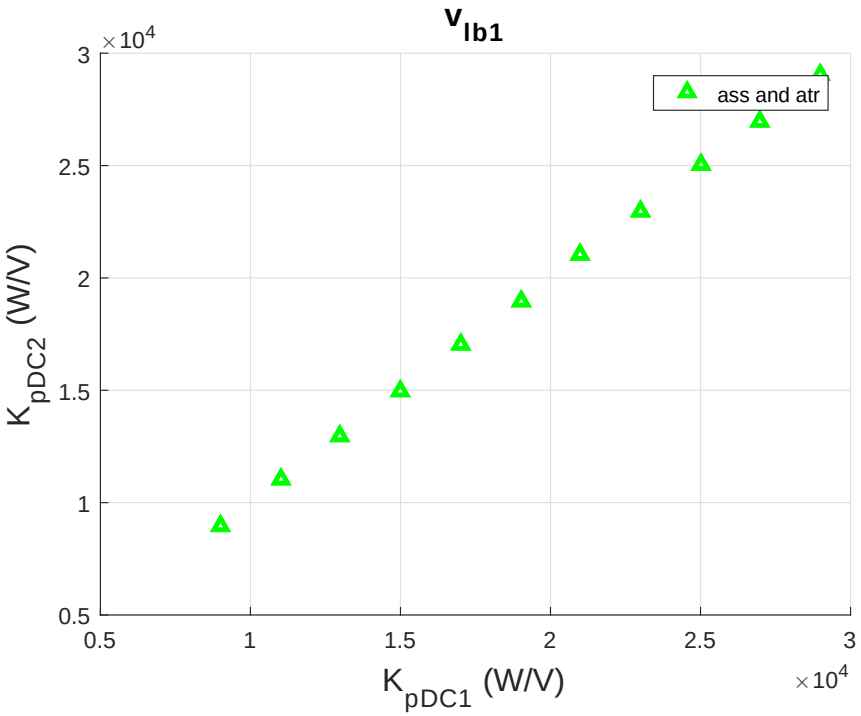

Figure B.211: Admissibility graph of voltage v_{lb1} from simulation 11 of Case 2

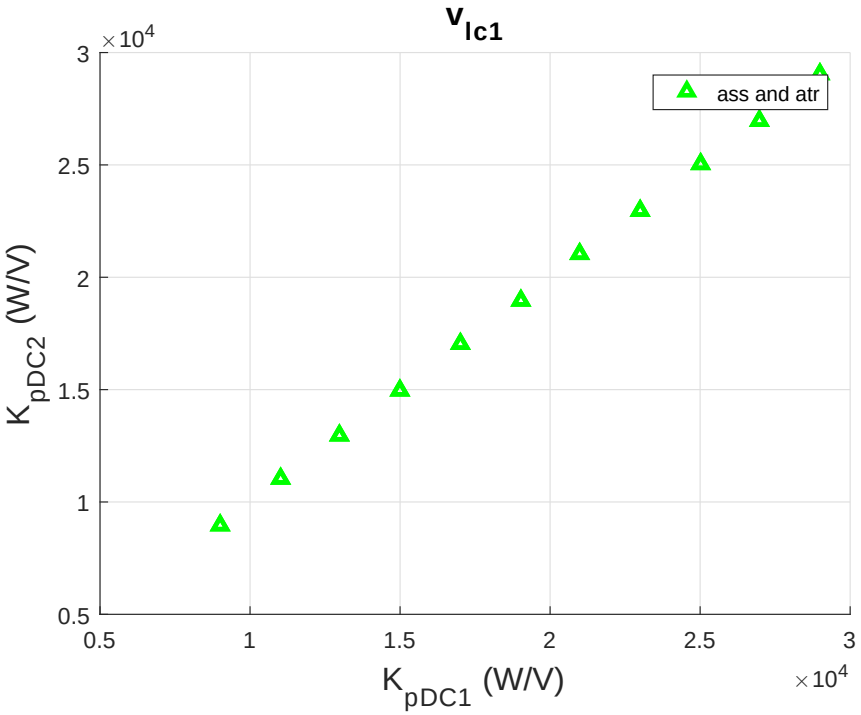

Figure B.212: Admissibility graph of voltage v_{lc1} from simulation 11 of Case 2

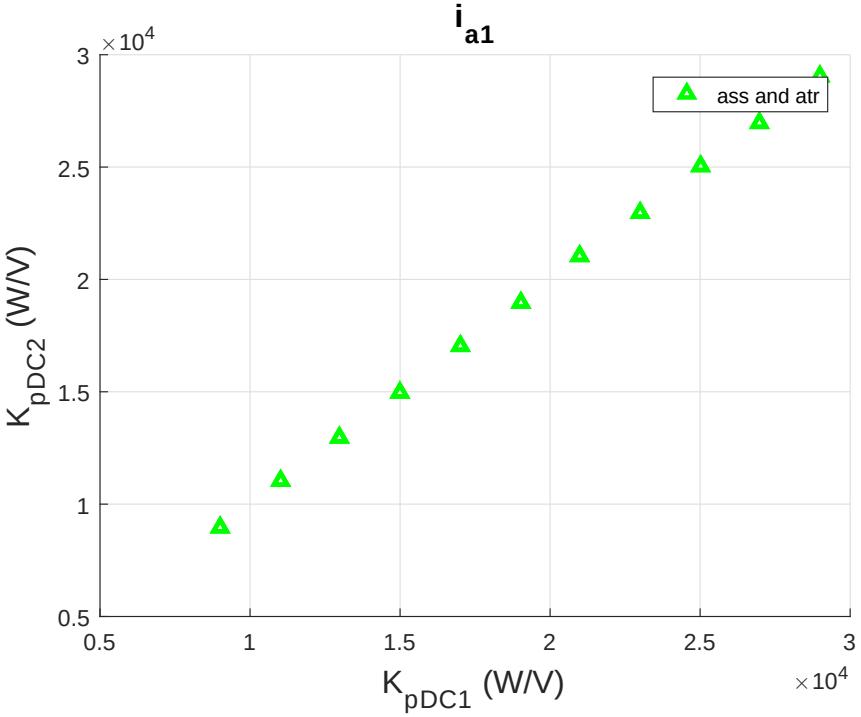

Figure B.213: Admissibility graph of current i_{a1} from simulation 11 of Case 2

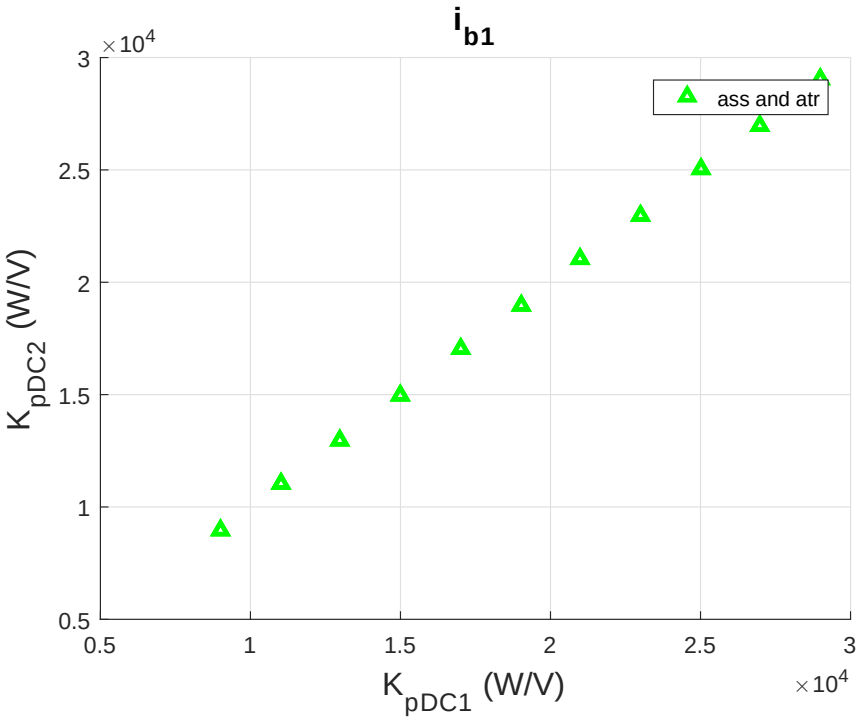

Figure B.214: Admissibility graph of current i_{b1} from simulation 11 of Case 2

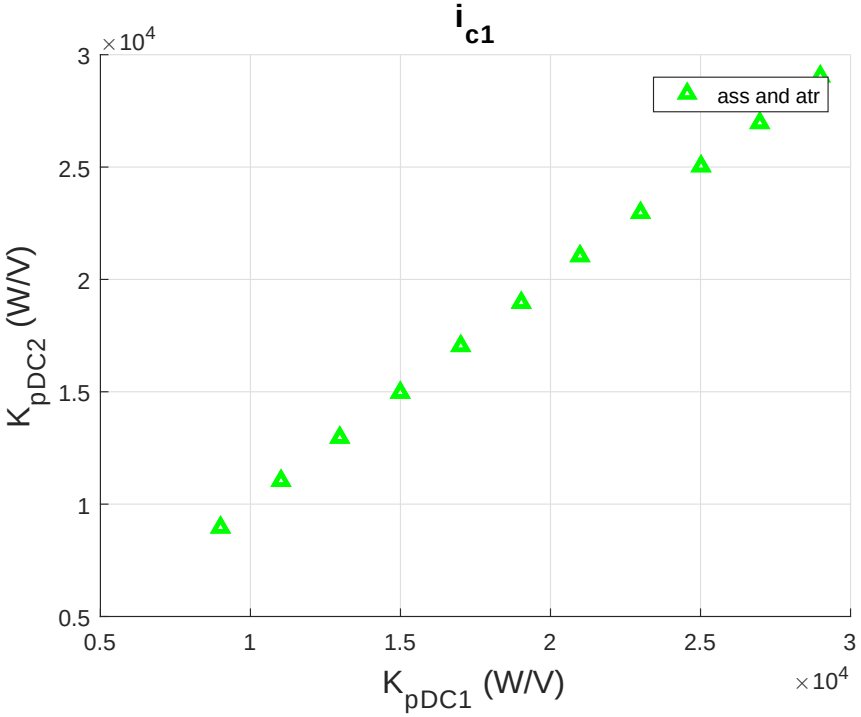

Figure B.215: Admissibility graph of current i_{c1} from simulation 11 of Case 2

B.11.3 Voltages and currents of power converter 2

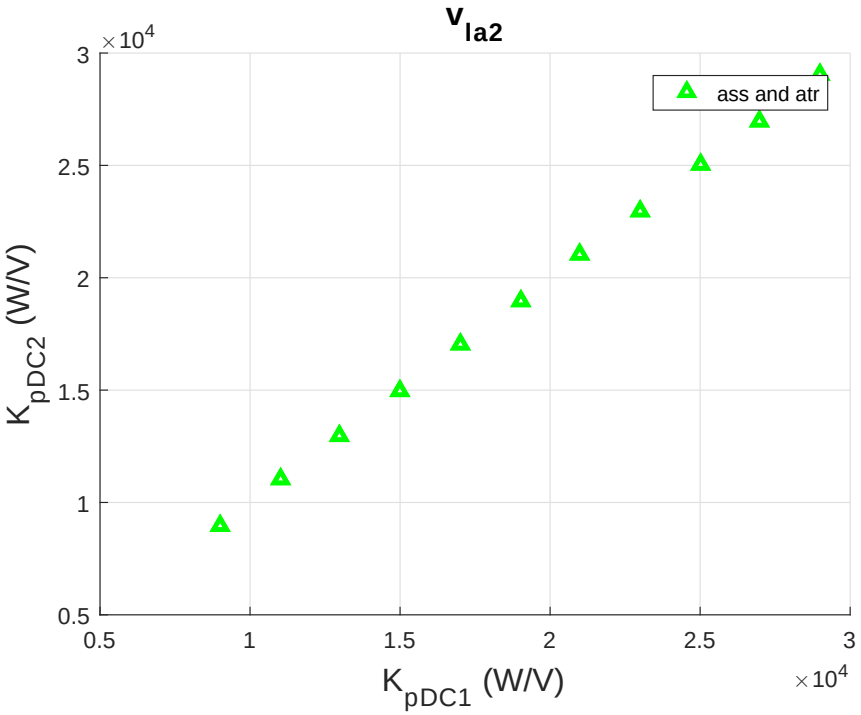

Figure B.216: Admissibility graph of voltage v_{la2} from simulation 11 of Case 2

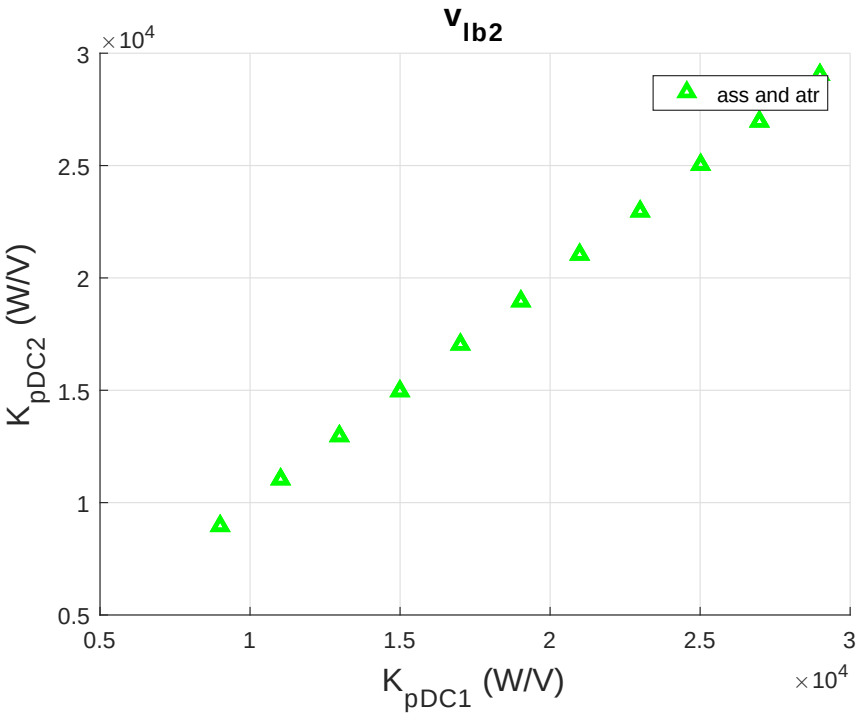

Figure B.217: Admissibility graph of voltage v_{lb2} from simulation 11 of Case 2

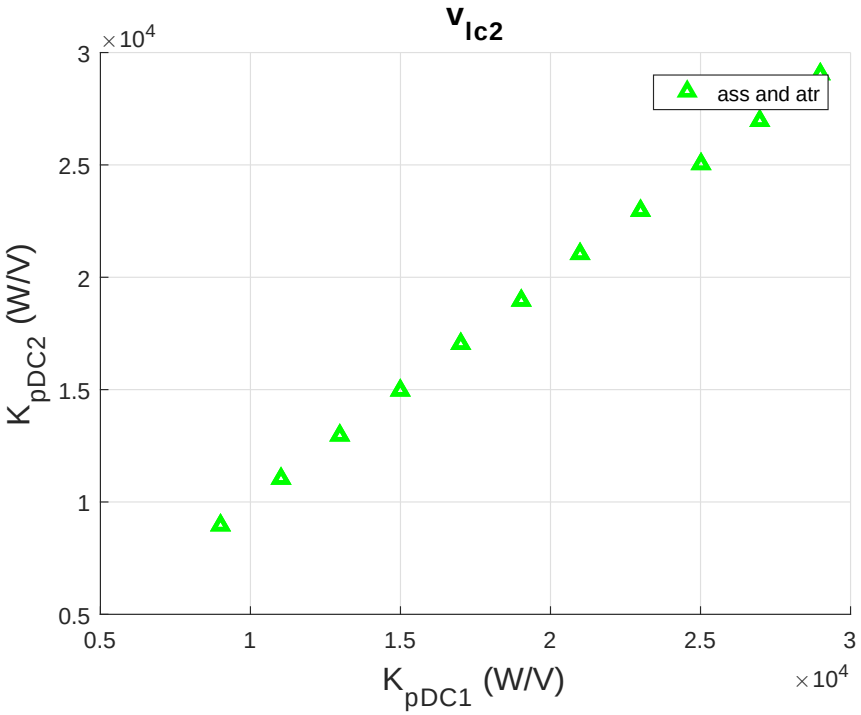

Figure B.218: Admissibility graph of voltage v_{lc2} from simulation 11 of Case 2

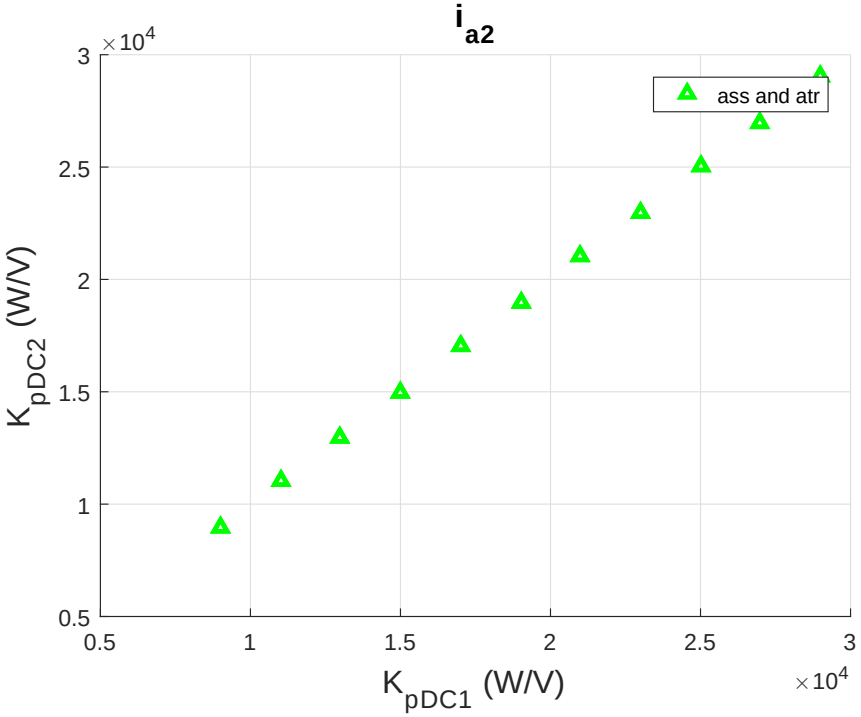

Figure B.219: Admissibility graph of current i_{a2} from simulation 11 of Case 2

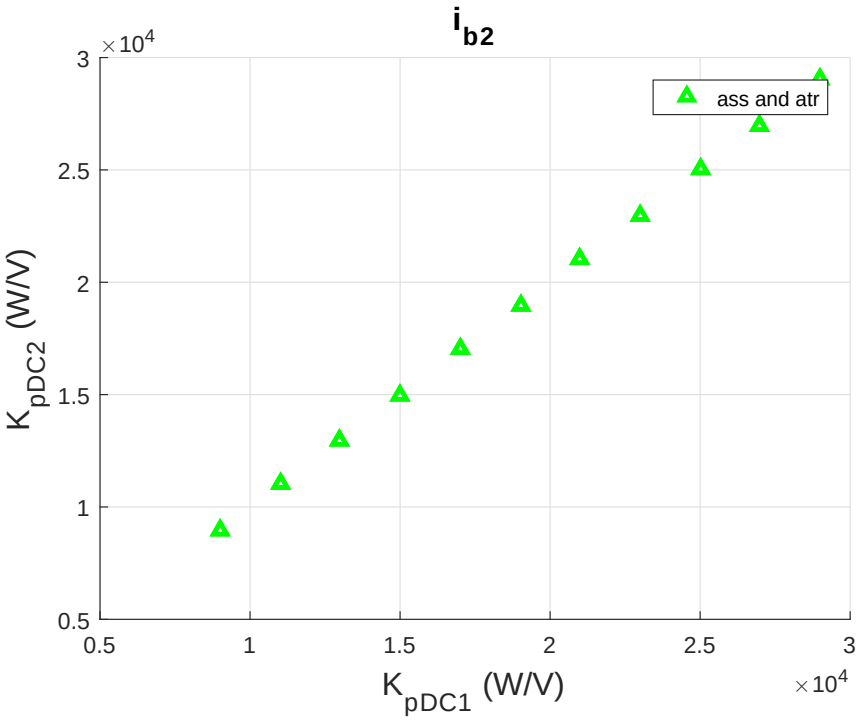

Figure B.220: Admissibility graph of current i_{b2} from simulation 11 of Case 2

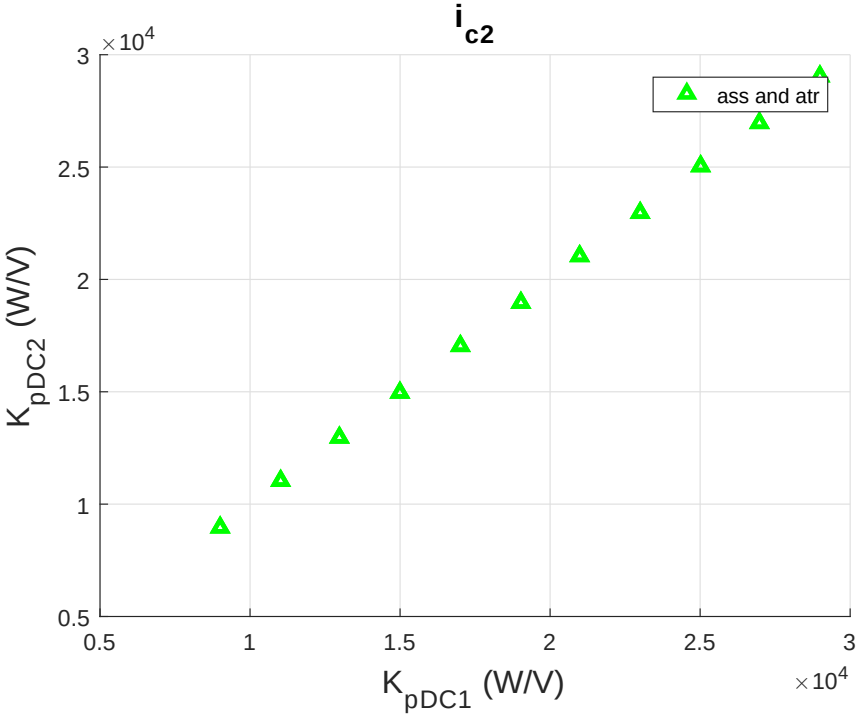

Figure B.221: Admissibility graph of current i_{c2} from simulation 11 of Case 2

Annex C

Simulations of Case 3: Disconnection of a WFVSC converter

The solver chosen for each simulation has been the ode4 (Runge-Kutta) with a fixed-step size of 10^{-5}.

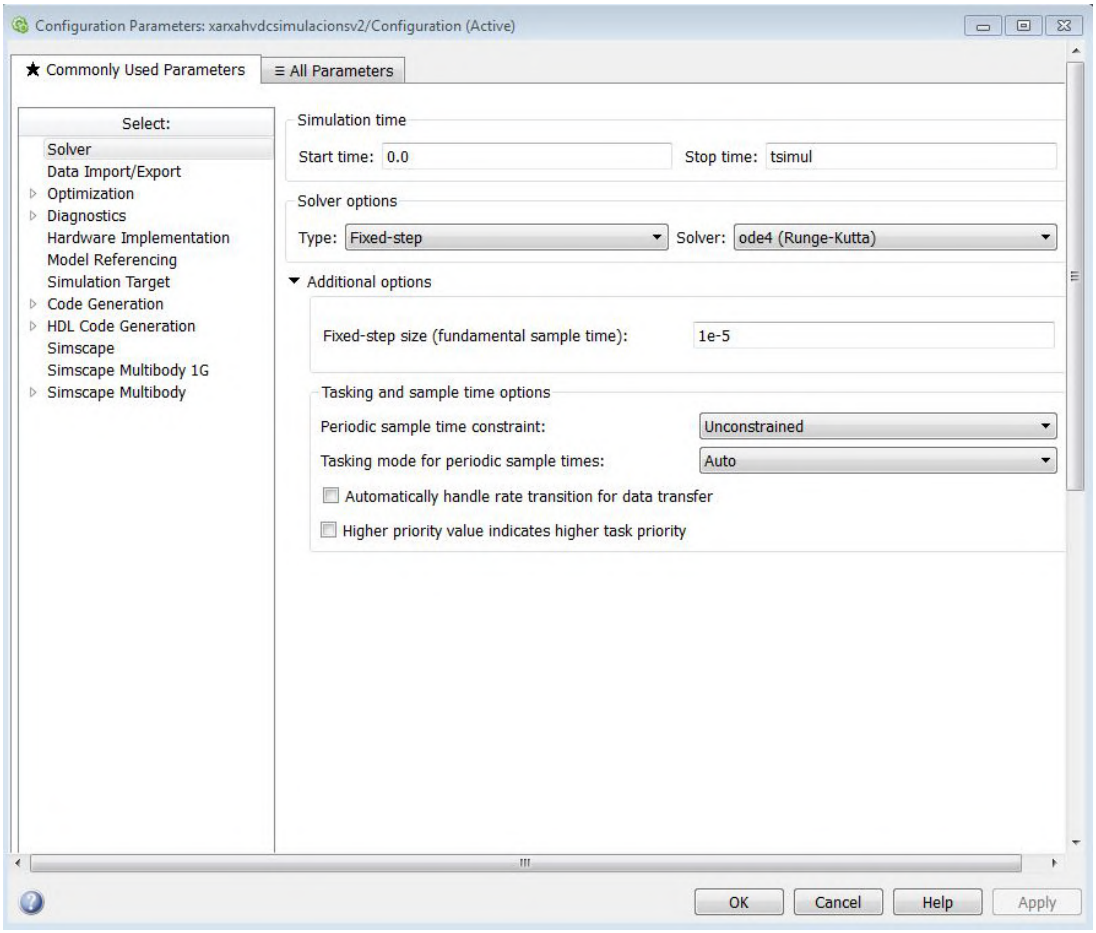

Figure C.1: Configuration parameters of the solver

C.1 Simulation 1

Simulation 1: $K_{pDC} \in [10000, 50000]$ with a step of 5000. In total 9 simulations for each electrical magnitude.

C.1.1 Voltages and currents of the multi-terminal HVDC grid

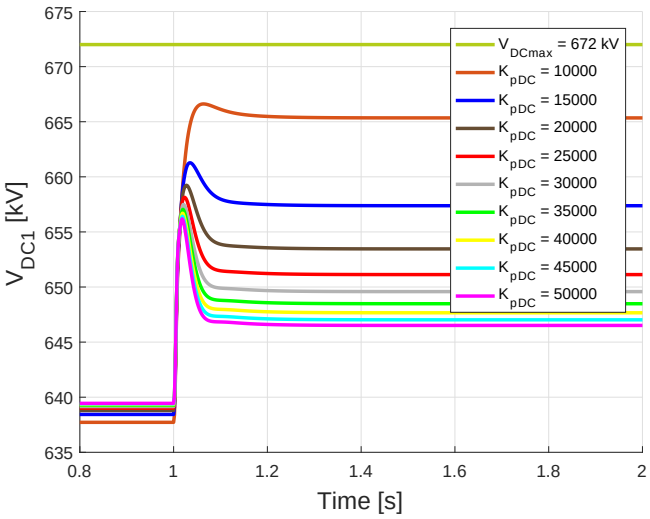

Figure C.2: Voltage V_{DC1} from simulation 1 of Case 3

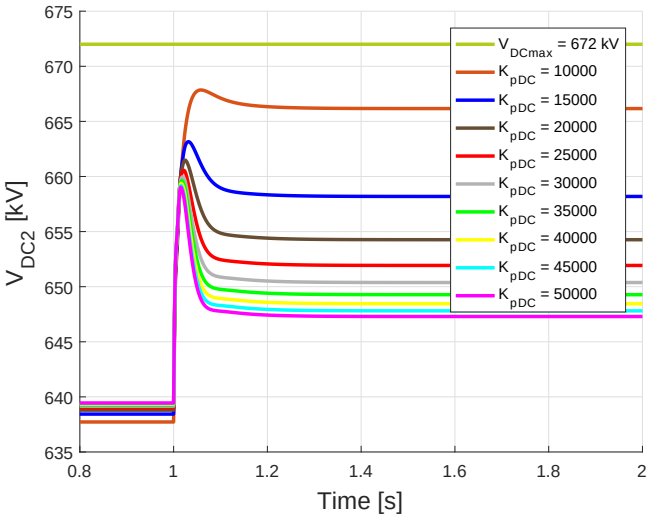

Figure C.3: Voltage V_{DC2} from simulation 1 of Case 3

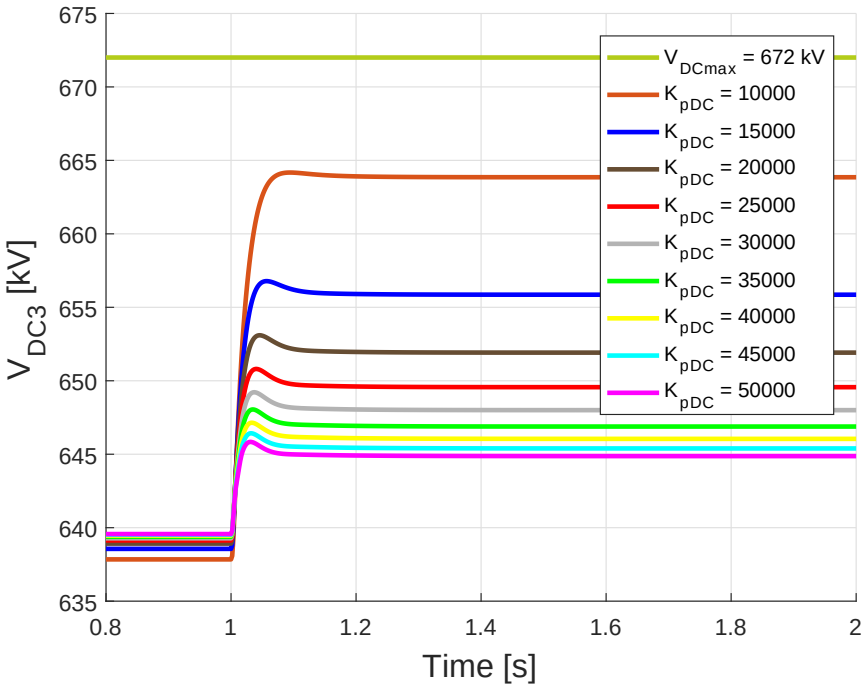

Figure C.4: Voltage V_{DC3} from simulation 1 of Case 3

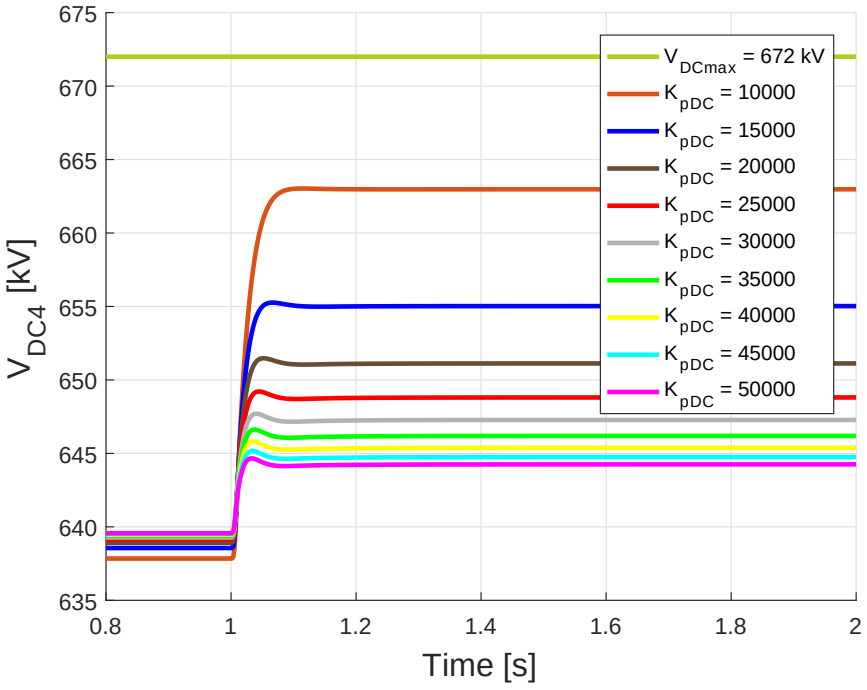

Figure C.5: Voltage V_{DC4} from simulation 1 of Case 3

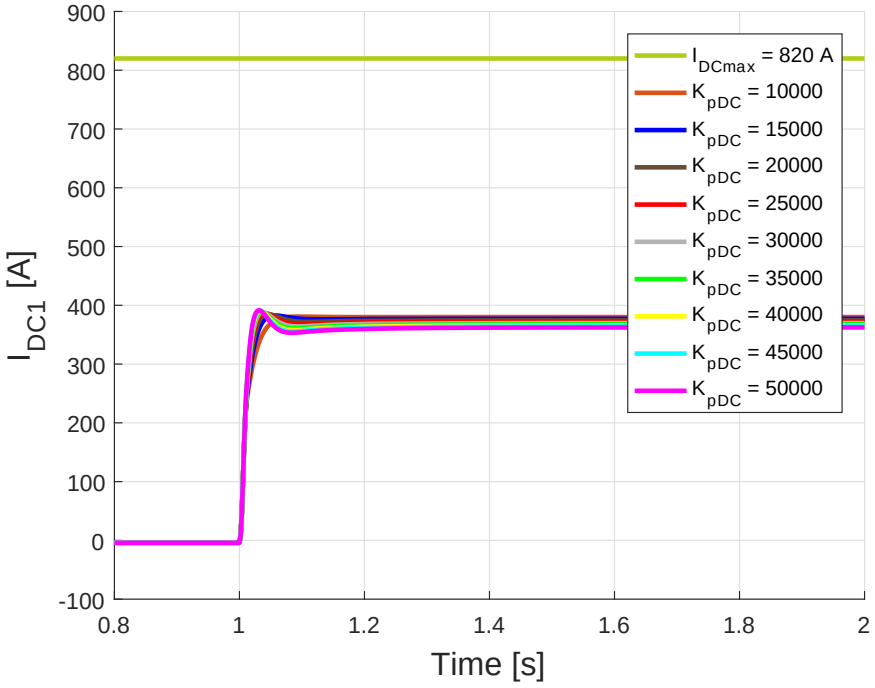

Figure C.6: Current I_{DC1} from simulation 1 of Case 3

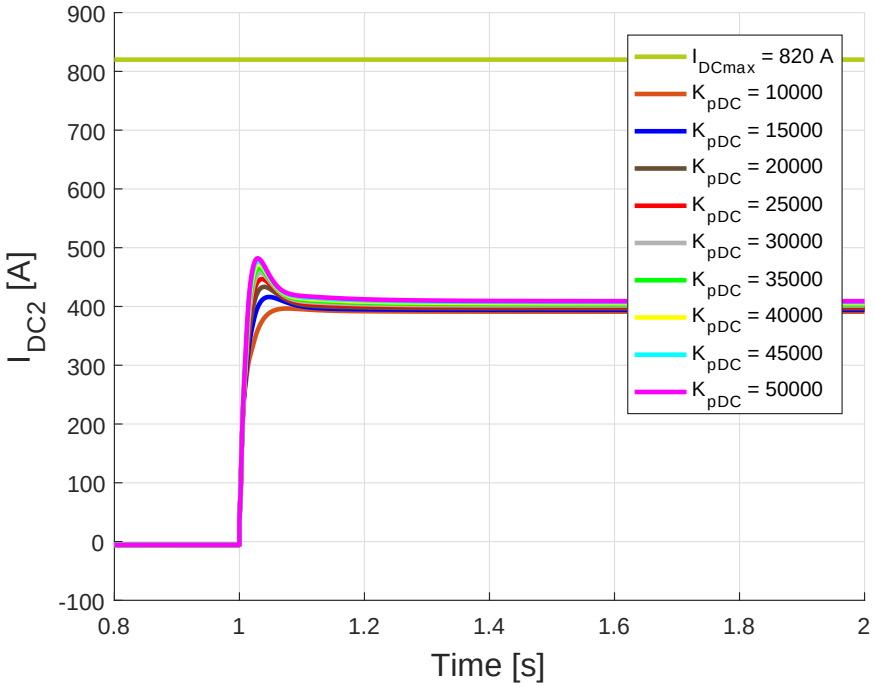

Figure C.7: Current I_{DC2} from simulation 1 of Case 3

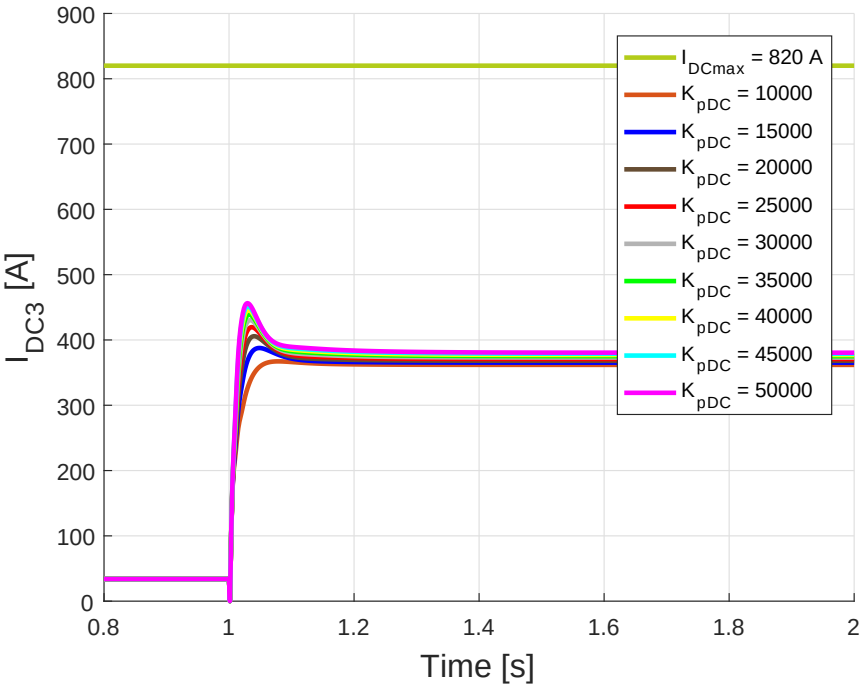

Figure C.8: Current I_{DC3} from simulation 1 of Case 3

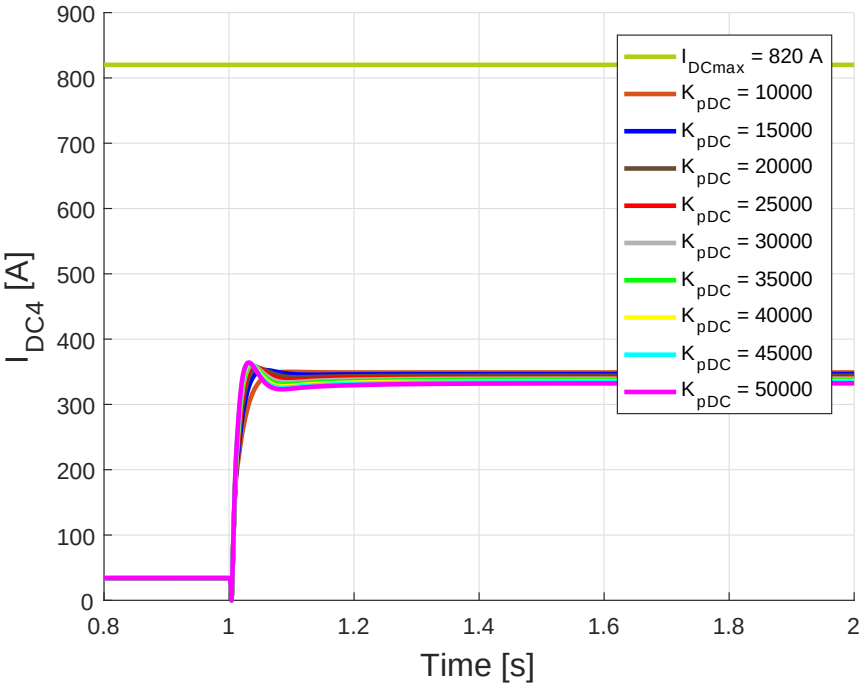

Figure C.9: Current I_{DC4} from simulation 1 of Case 3

C.1.2 Voltages and currents of power converter 1

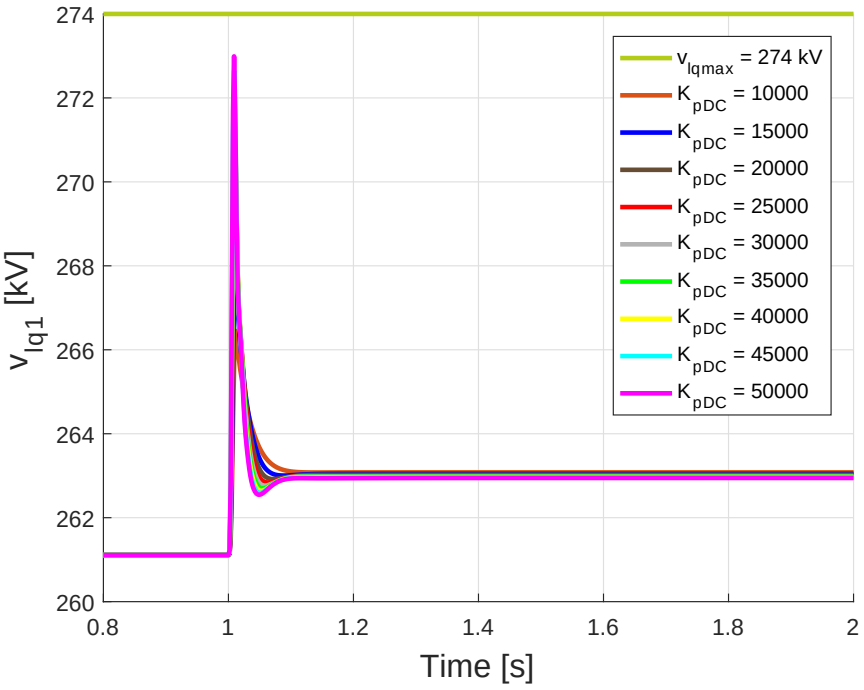

Figure C.10: Voltage v_{lq1} from simulation 1 of Case 3

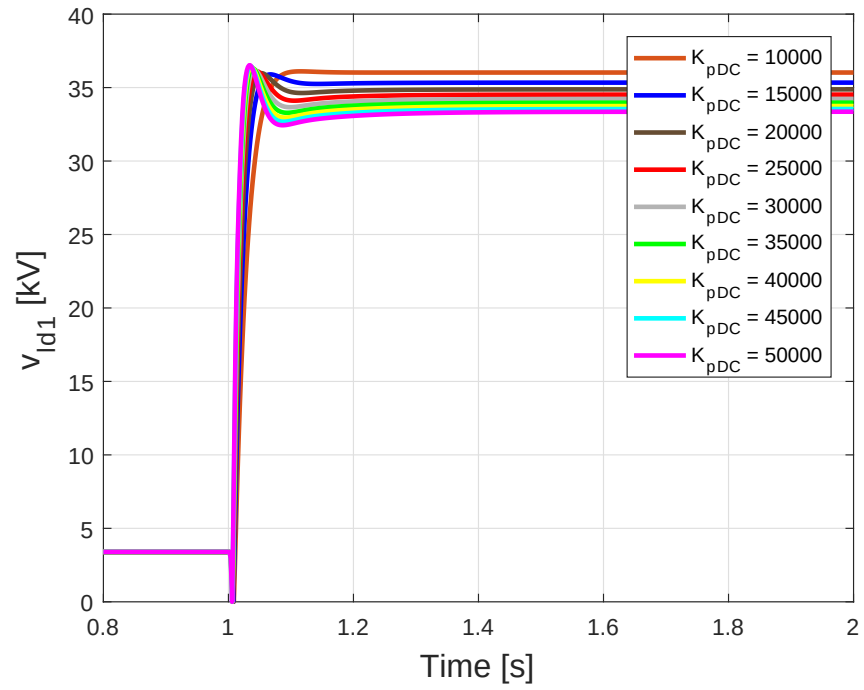

Figure C.11: Voltage v_{ld1} from simulation 1 of Case 3

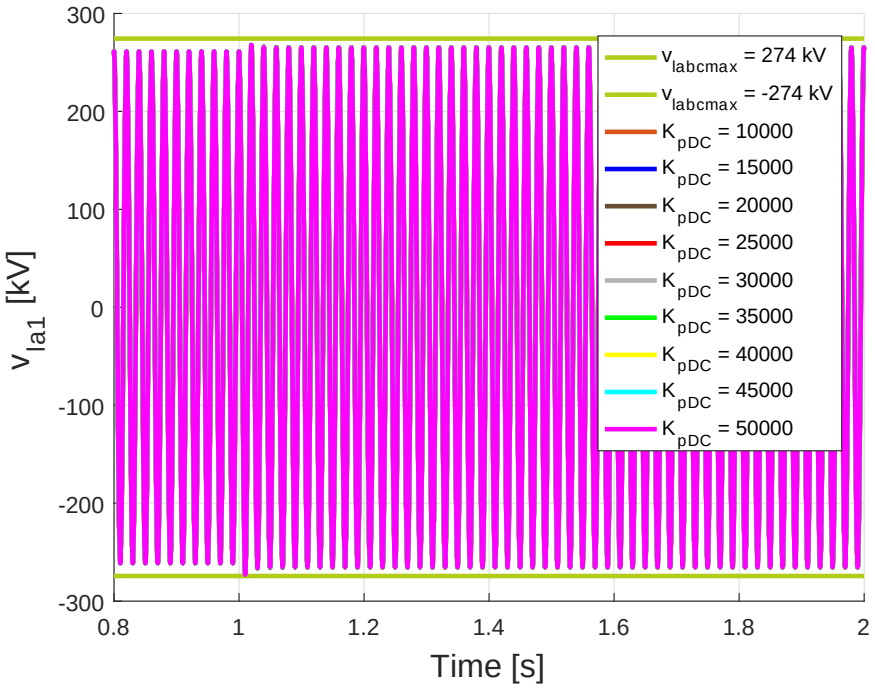

Figure C.12: Voltage v_{la1} from simulation 1 of Case 3

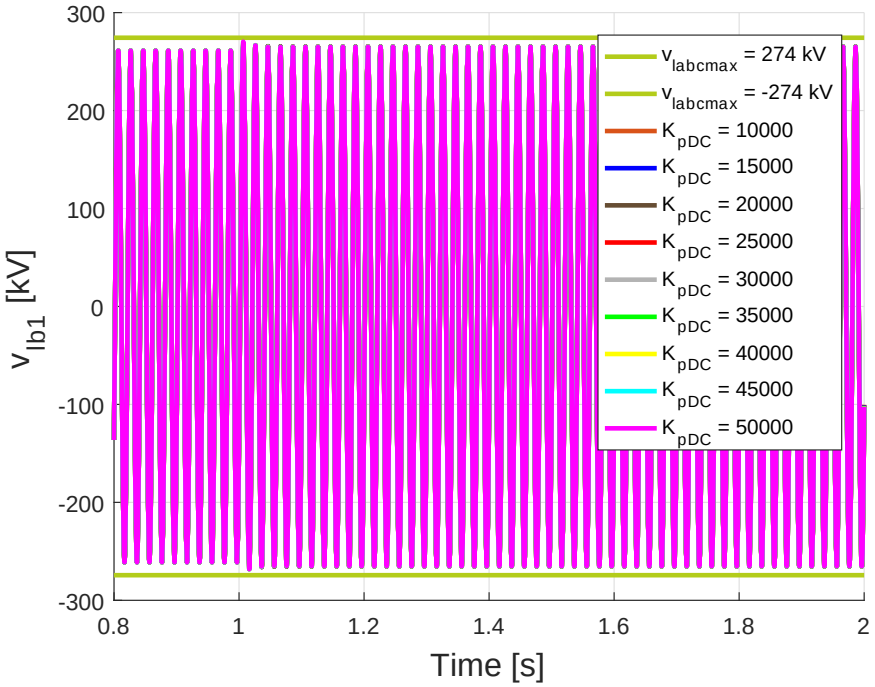

Figure C.13: Voltage v_{lb1} from simulation 1 of Case 3

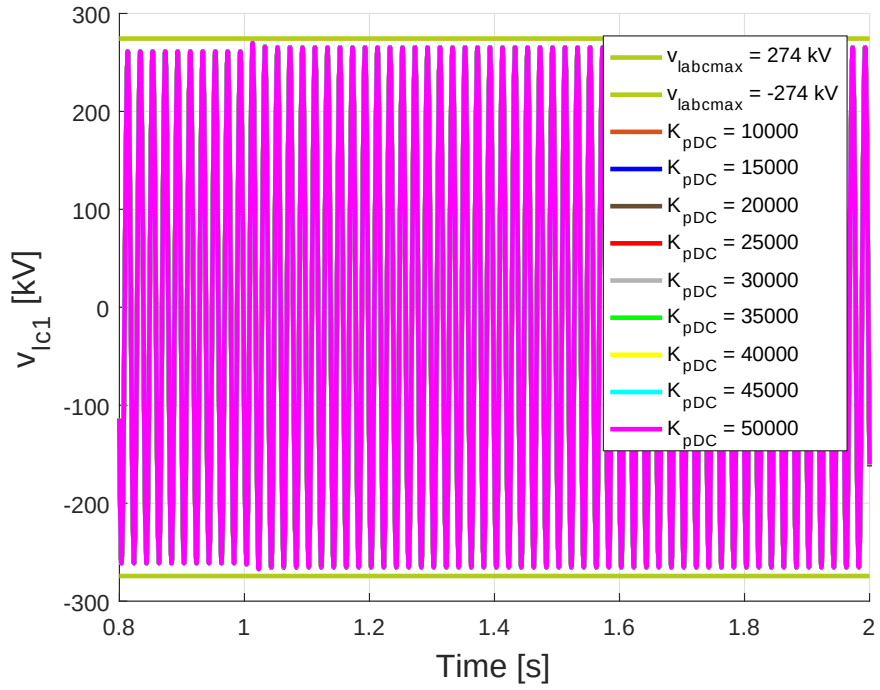

Figure C.14: Voltage v_{lc1} from simulation 1 of Case 3

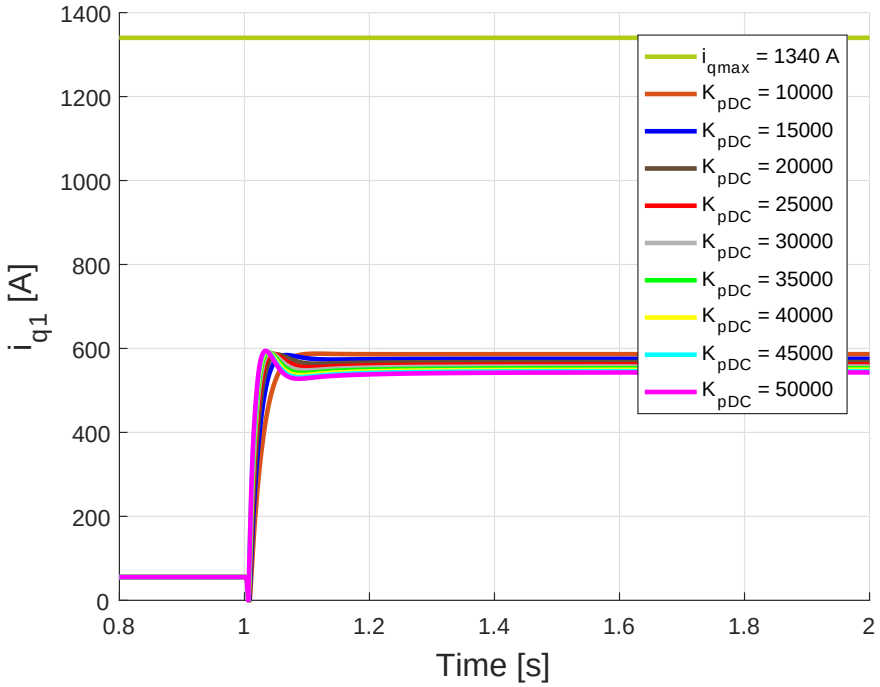

Figure C.15: Current i_{q1} from simulation 1 of Case 3

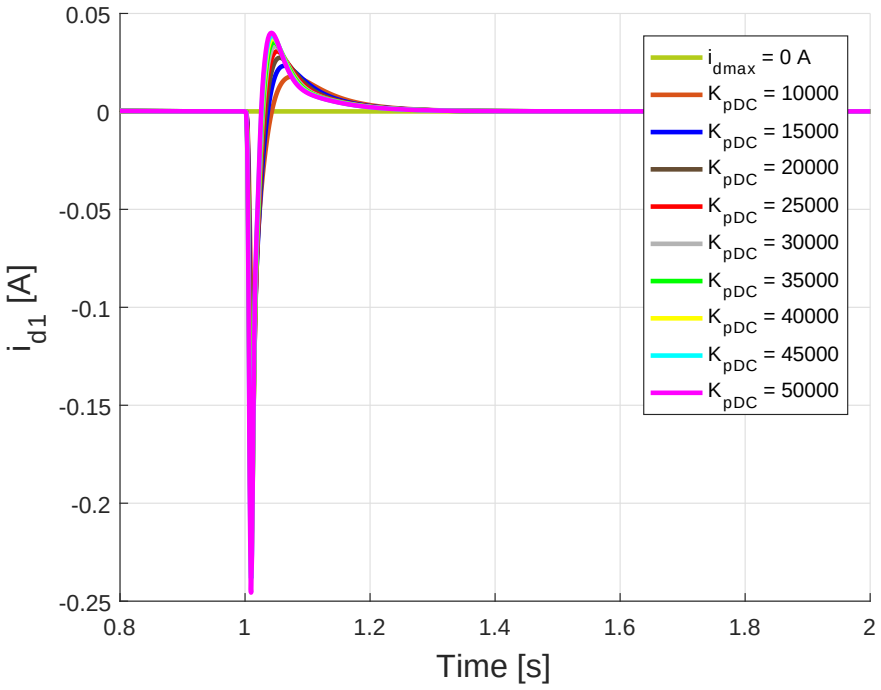

Figure C.16: Current i_{d1} from simulation 1 of Case 3

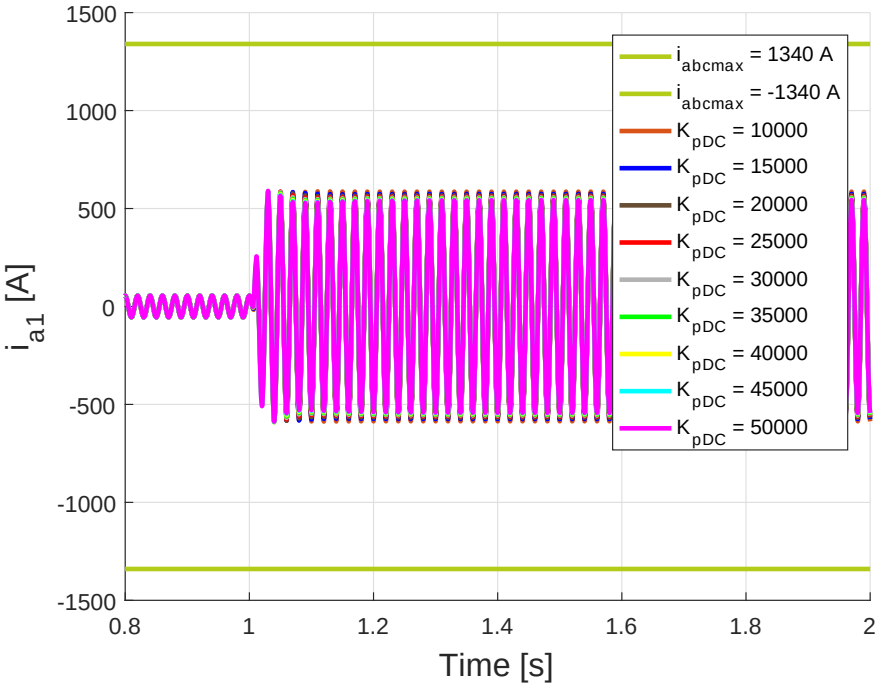

Figure C.17: Current i_{a1} from simulation 1 of Case 3

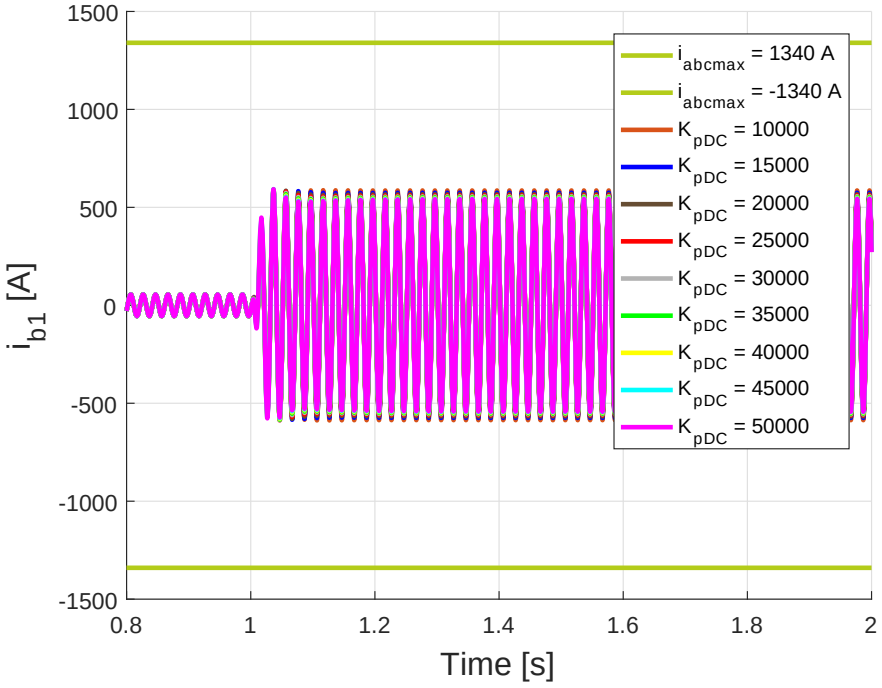

Figure C.18: Current i_{b1} from simulation 1 of Case 3

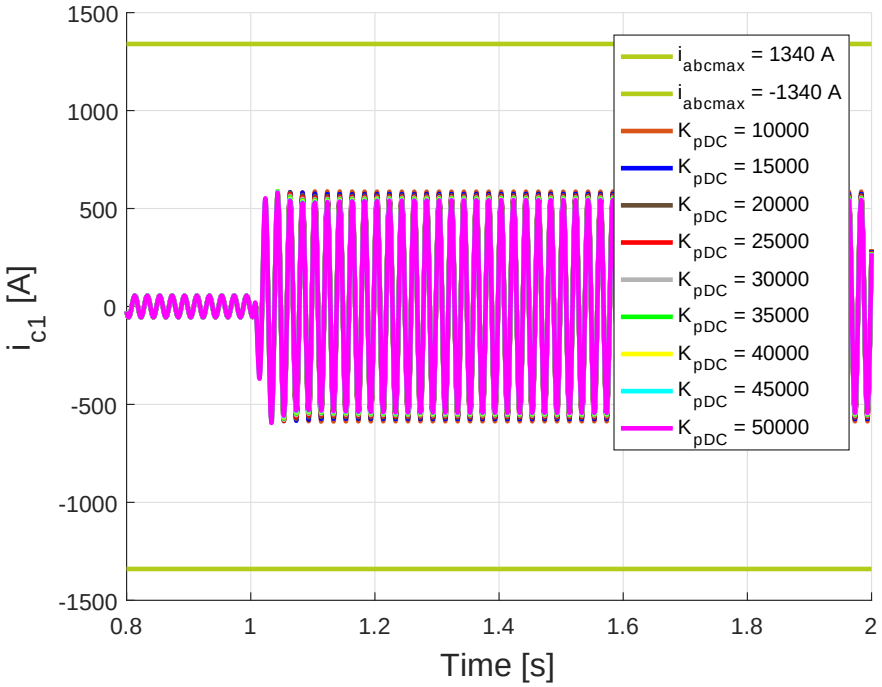

Figure C.19: Current i_{c1} from simulation 1 of Case 3

C.1.3 Voltages and currents of power converter 2

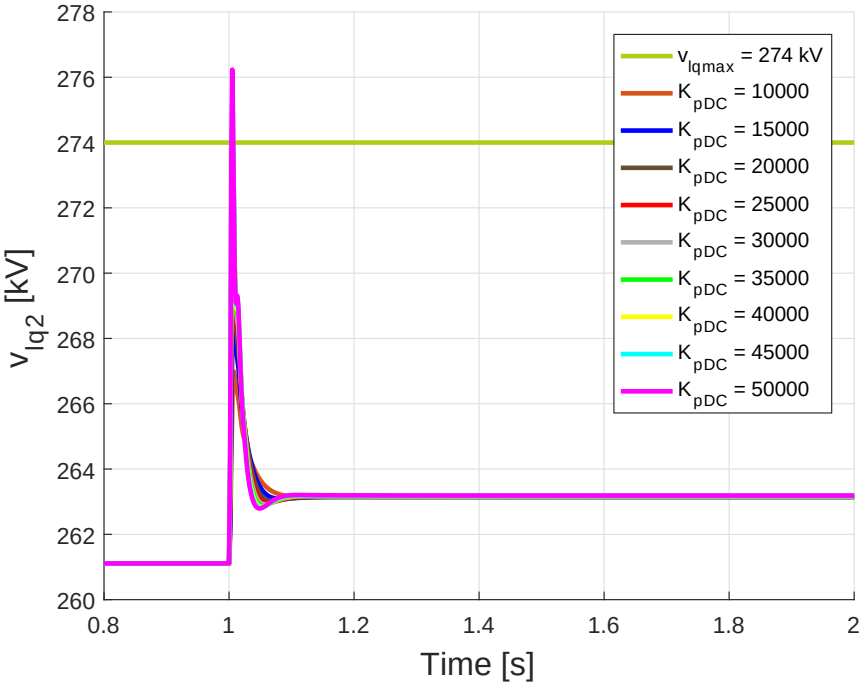

Figure C.20: Voltage v_{lq2} from simulation 1 of Case 3

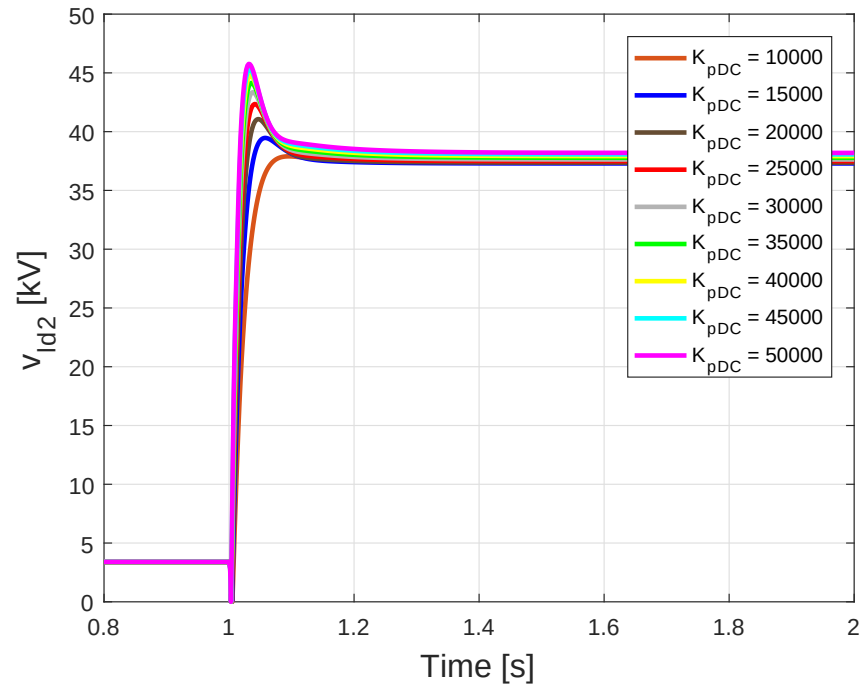

Figure C.21: Voltage v_{ld2} from simulation 1 of Case 3

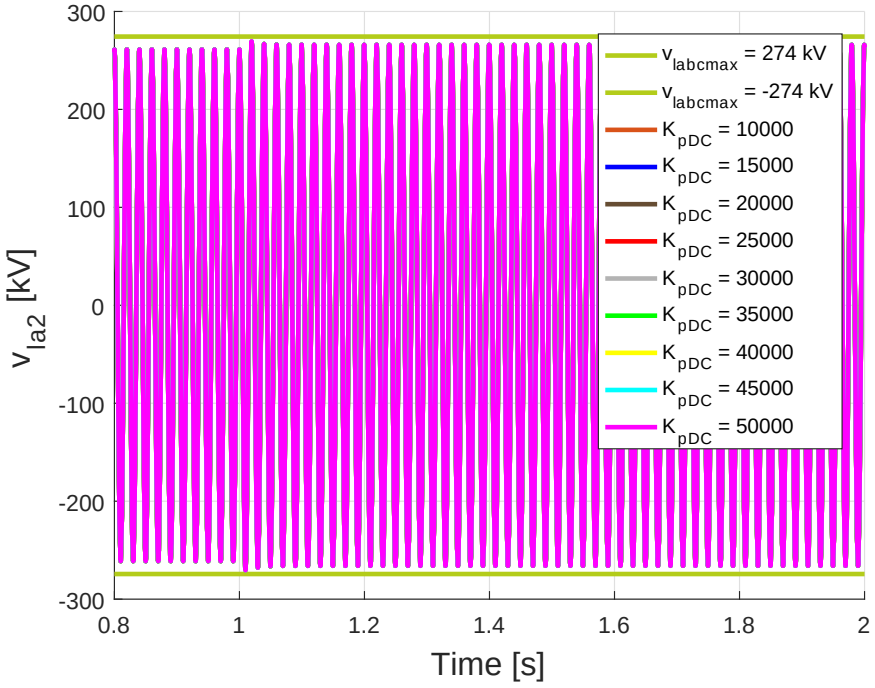

Figure C.22: Voltage v_{la2} from simulation 1 of Case 3

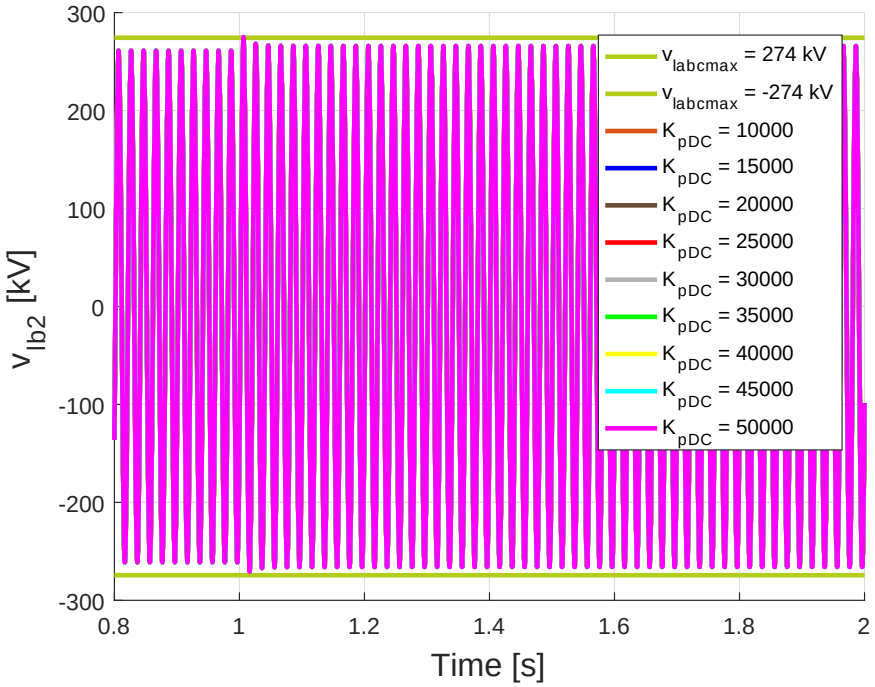

Figure C.23: Voltage v_{lb2} from simulation 1 of Case 3

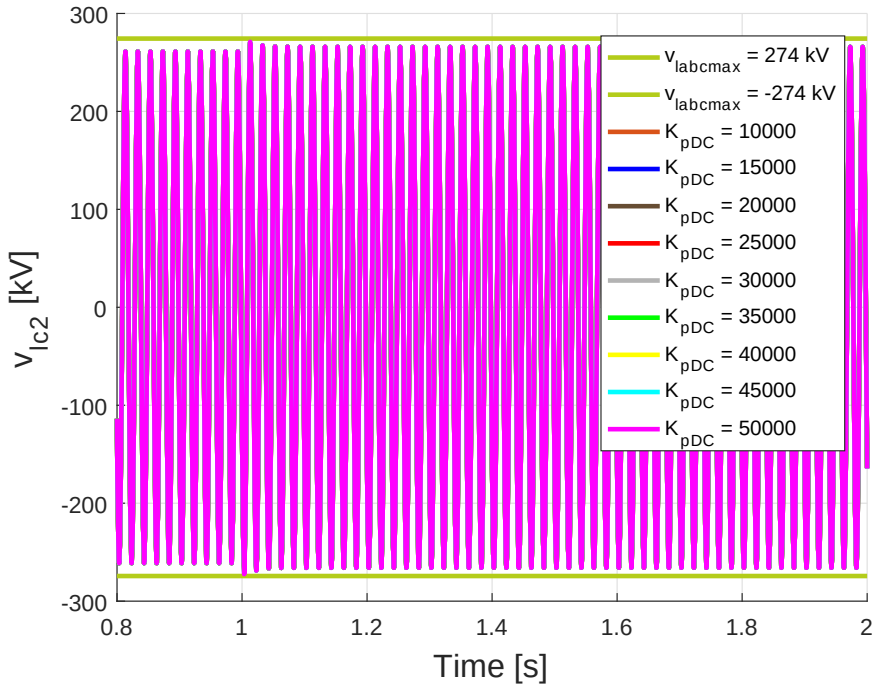

Figure C.24: Voltage v_{lc2} from simulation 1 of Case 3

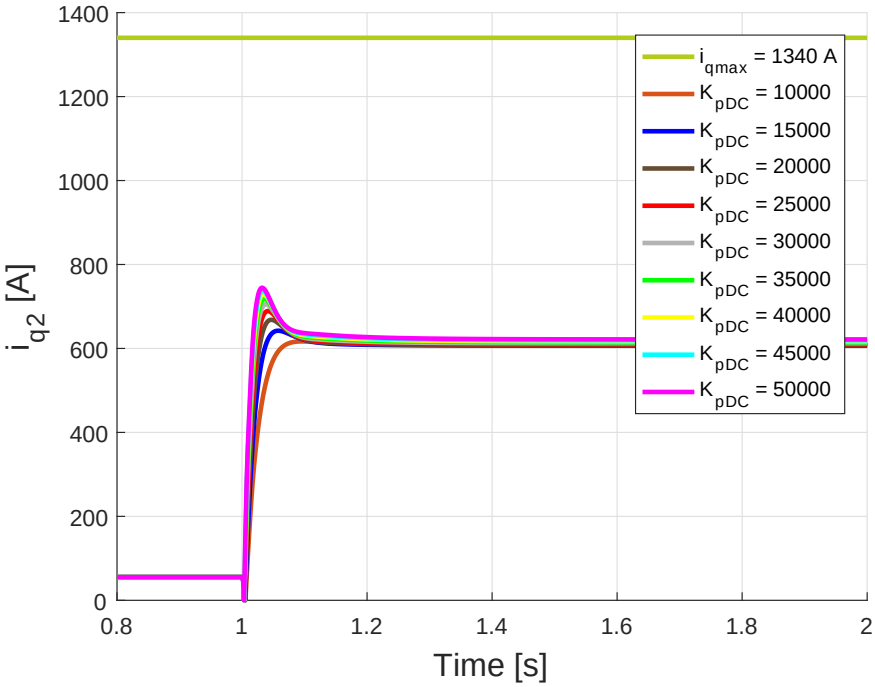

Figure C.25: Current i_{q2} from simulation 1 of Case 3

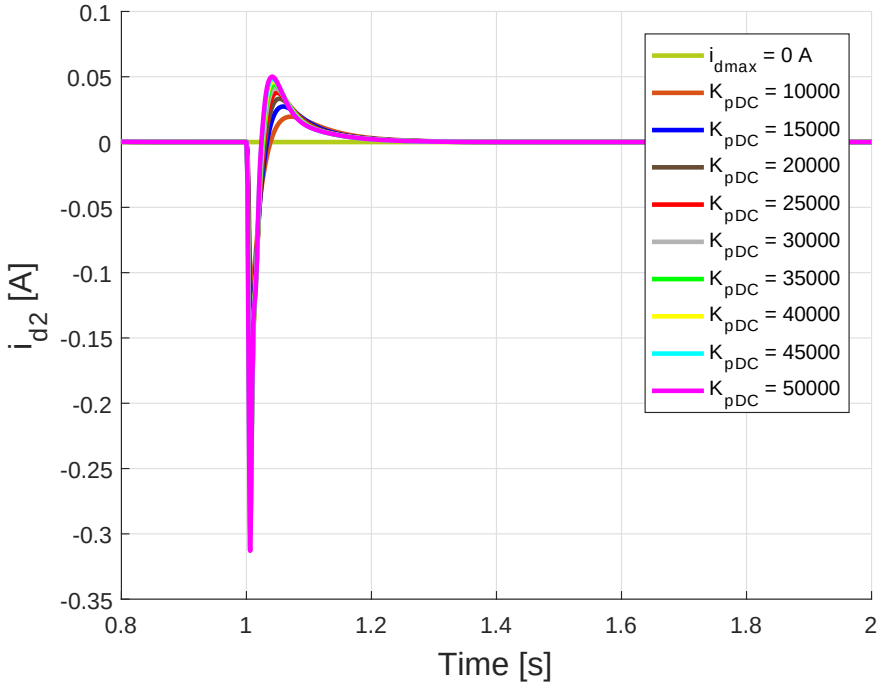

Figure C.26: Current i_{d2} from simulation 1 of Case 3

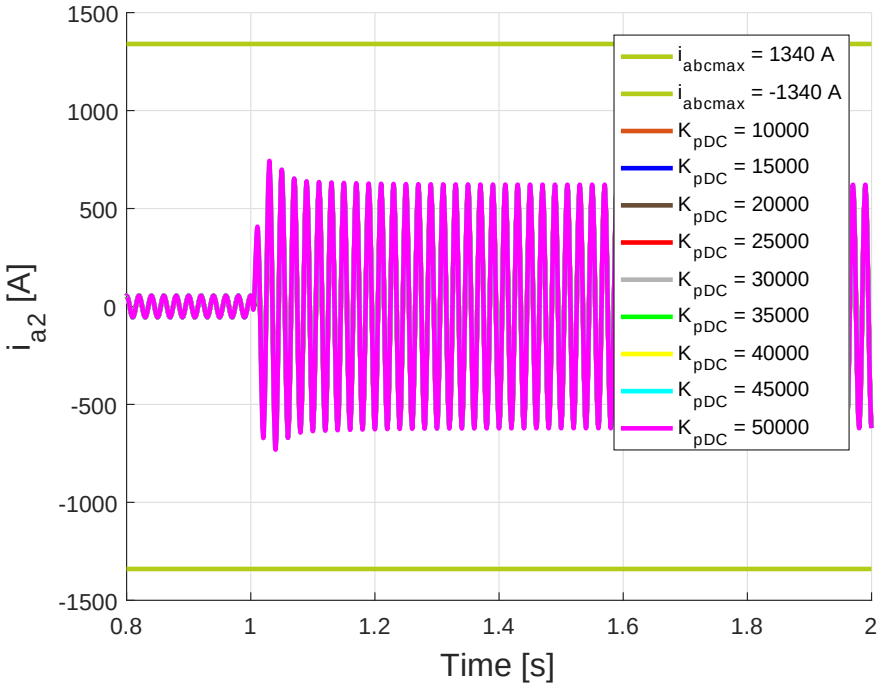

Figure C.27: Current i_{a2} from simulation 1 of Case 3

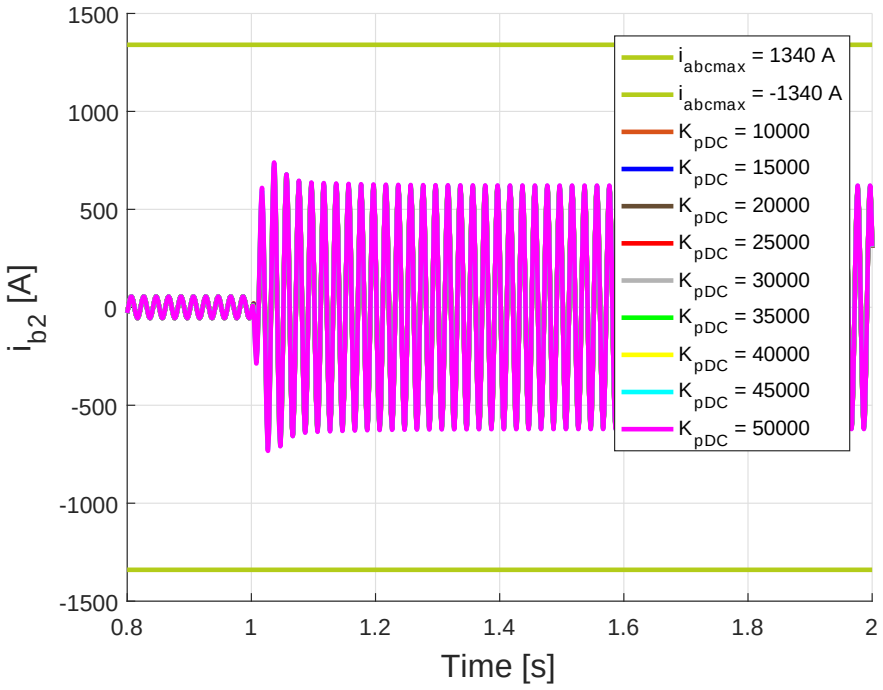

Figure C.28: Current i_{b2} from simulation 1 of Case 3

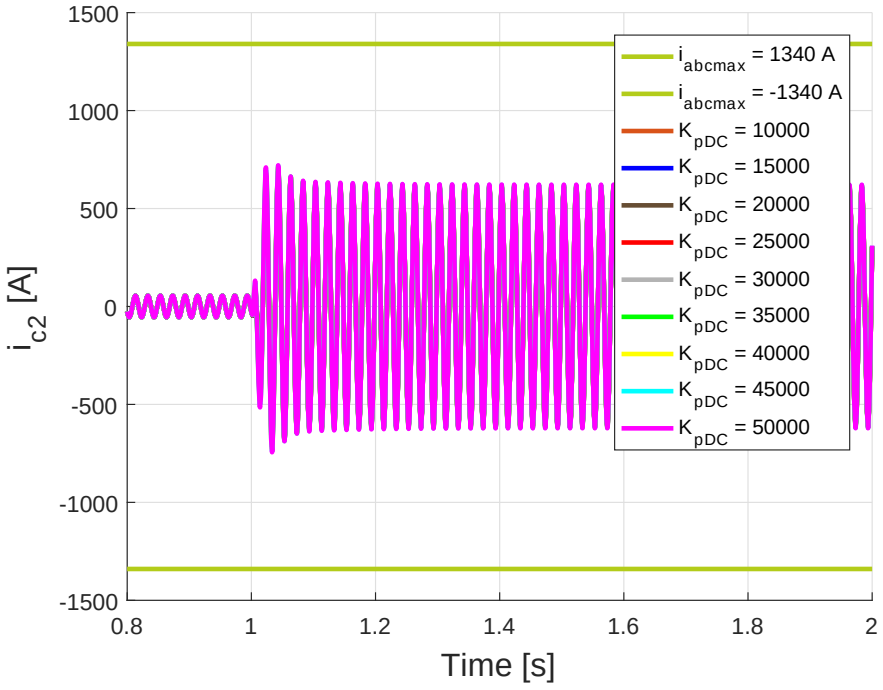

Figure C.29: Current i_{c2} from simulation 1 of Case 3

Annex D

Mathematical expressions

D.1 Demonstration of the current loop equation

In this Annex is going to demonstrate to pass from D.1 to D.2.

$$v_{zqd0} - v_{lqd0} = \begin{bmatrix} r_l & 0 & 0 \\ 0 & r_l & 0 \\ 0 & 0 & r_l \end{bmatrix} i_{qd0} + T(\theta) \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} \frac{dT(\theta)^{-1}}{dt} i_{qd0} + \\ + T(\theta) \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} T(\theta)^{-1} \frac{di_{qd0}}{dt} \tag{D.1}$$

$$\begin{bmatrix} v_{zq} \\ v_{zd} \end{bmatrix} - \begin{bmatrix} v_{lq} \\ v_{ld} \end{bmatrix} = \begin{bmatrix} r_l & l_l \cdot \omega \\ -l_l \cdot \omega & r_l \end{bmatrix} \begin{bmatrix} i_q \\ i_d \end{bmatrix} + \begin{bmatrix} l_l & 0 \\ 0 & l_l \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_q \\ i_d \end{bmatrix} \tag{D.2}$$

First of all, it is known that one matrix multiplied by its inverse results in the identity matrix ($A \cdot A^{-1} = I$). Therefore:

$$T(\theta) \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} T(\theta)^{-1} \frac{di_{qd0}}{dt} = \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \frac{di_{qd0}}{dt} = \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} \frac{di_{qd0}}{dt} \tag{D.3}$$

It is going to resolve the following:

$$T(\theta) \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} \frac{dT(\theta)^{-1}}{dt} \tag{D.4}$$

It is important to remember the aspect of the transformation matrix and its inverse:

$$T(\theta) = \frac{2}{3}\begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\cdot\pi}{3}\right) & \cos\left(\theta + \frac{2\cdot\pi}{3}\right) \\ \sin(\theta) & \sin\left(\theta - \frac{2\cdot\pi}{3}\right) & \sin\left(\theta + \frac{2\cdot\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \tag{D.5}$$

$$T^{-1}(\theta) = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 1 \\ \cos\left(\theta - \frac{2\cdot\pi}{3}\right) & \sin\left(\theta - \frac{2\cdot\pi}{3}\right) & 1 \\ \cos\left(\theta + \frac{2\cdot\pi}{3}\right) & \sin\left(\theta + \frac{2\cdot\pi}{3}\right) & 1 \end{bmatrix} \tag{D.6}$$

The time derivative of the inverse matrix is:

$$\frac{dT(\theta)^{-1}}{dt} = \begin{bmatrix} -\sin(\theta)\cdot\dot{\theta} & \cos(\theta)\cdot\dot{\theta} & 0 \\ -\sin\left(\theta - \frac{2\cdot\pi}{3}\right)\cdot\dot{\theta} & \cos\left(\theta - \frac{2\cdot\pi}{3}\right)\cdot\dot{\theta} & 0 \\ -\sin\left(\theta + \frac{2\cdot\pi}{3}\right)\cdot\dot{\theta} & \cos\left(\theta + \frac{2\cdot\pi}{3}\right)\cdot\dot{\theta} & 0 \end{bmatrix} \tag{D.7}$$

Substituting D.5 and D.7 in D.4 and operating, it is obtained:

$$T(\theta)\begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix}\frac{dT(\theta)^{-1}}{dt} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \tag{D.8}$$

It is important to remark that $\dot{\theta} = \omega$ because the time derivative of the angle is the angular velocity. The terms of this matrix are presented in continuation:

$$a_{11} = -\frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)\cdot\sin(\theta) + \cos\left(\theta - \frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta - \frac{2\cdot\pi}{3}\right) + \right.$$
$$\left. + \cos\left(\theta + \frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta + \frac{2\cdot\pi}{3}\right)\right);$$

$$a_{12} = \frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)^2 + \cos\left(\theta - \frac{2\cdot\pi}{3}\right)^2 + \cos\left(\theta + \frac{2\cdot\pi}{3}\right)^2\right);$$

$$a_{13} = 0;$$

$$a_{21} = -\frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\sin(\theta)^2 + \sin\left(\theta - \frac{2\cdot\pi}{3}\right)^2 + \sin\left(\theta + \frac{2\cdot\pi}{3}\right)^2\right);$$

$$a_{22} = \frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)\cdot\sin(\theta) + \cos\left(\theta - \frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta - \frac{2\cdot\pi}{3}\right) + \right.$$
$$\left. + \cos\left(\theta + \frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta + \frac{2\cdot\pi}{3}\right)\right);$$

$$a_{23} = 0;$$

$$a_{31} = -\frac{1}{3}\cdot l_l\cdot\omega\cdot\left(\sin(\theta) + \sin\left(\theta-\frac{2\cdot\pi}{3}\right) + \sin\left(\theta+\frac{2\cdot\pi}{3}\right)\right);$$

$$a_{32} = \frac{1}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta) + \cos\left(\theta-\frac{2\cdot\pi}{3}\right) + \cos\left(\theta+\frac{2\cdot\pi}{3}\right)\right);$$

$$a_{33} = 0;$$

Before simplifying these terms, in continuation the relationships between the cosine and the sine are presented:

$$\begin{aligned}
\cos(\alpha+\beta) &= \cos(\alpha)\cdot\cos(\beta) - \sin(\alpha)\cdot\sin(\beta)\\
\cos(\alpha-\beta) &= \cos(\alpha)\cdot\cos(\beta) + \sin(\alpha)\cdot\sin(\beta)\\
\sin(\alpha+\beta) &= \sin(\alpha)\cdot\cos(\beta) + \cos(\alpha)\cdot\sin(\beta)\\
\sin(\alpha-\beta) &= \sin(\alpha)\cdot\cos(\beta) - \cos(\alpha)\cdot\sin(\beta)
\end{aligned}$$

With these properties of cosines and sines, it is going to calculate the expressions of the matrix terms:

$$\cos\left(\theta-\frac{2\cdot\pi}{3}\right) = \cos(\theta)\cdot\cos\left(\frac{2\cdot\pi}{3}\right) + \sin(\theta)\cdot\sin\left(\frac{2\cdot\pi}{3}\right) = \frac{1}{2}\cdot\left(-\cos(\theta) + \sin(\theta)\cdot\sqrt{3}\right)$$

$$\sin\left(\theta-\frac{2\cdot\pi}{3}\right) = \sin(\theta)\cdot\cos\left(\frac{2\cdot\pi}{3}\right) - \cos(\theta)\cdot\sin\left(\frac{2\cdot\pi}{3}\right) = -\frac{1}{2}\cdot\left(\sin(\theta) + \cos(\theta)\cdot\sqrt{3}\right)$$

$$\cos\left(\theta+\frac{2\cdot\pi}{3}\right) = \cos(\theta)\cdot\cos\left(\frac{2\cdot\pi}{3}\right) - \sin(\theta)\cdot\sin\left(\frac{2\cdot\pi}{3}\right) = -\frac{1}{2}\cdot\left(\cos(\theta) + \sin(\theta)\cdot\sqrt{3}\right)$$

$$\sin\left(\theta+\frac{2\cdot\pi}{3}\right) = \sin(\theta)\cdot\cos\left(\frac{2\cdot\pi}{3}\right) + \cos(\theta)\cdot\sin\left(\frac{2\cdot\pi}{3}\right) = \frac{1}{2}\cdot\left(-\sin(\theta) + \cos(\theta)\cdot\sqrt{3}\right)$$

$$\cos\left(\theta-\frac{2\cdot\pi}{3}\right)^2 = \frac{1}{4}\cdot\left(\cos(\theta)^2 - 2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3} + \sin(\theta)^2\cdot 3\right)$$

$$\cos\left(\theta+\frac{2\cdot\pi}{3}\right)^2 = \frac{1}{4}\cdot\left(\cos(\theta)^2 + 2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3} + \sin(\theta)^2\cdot 3\right)$$

$$\sin\left(\theta-\frac{2\cdot\pi}{3}\right)^2 = \frac{1}{4}\cdot\left(\sin(\theta)^2 + 2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3} + \cos(\theta)^2\cdot 3\right)$$

$$\sin\left(\theta+\frac{2\cdot\pi}{3}\right)^2 = \frac{1}{4}\cdot\left(\sin(\theta)^2 - 2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3} + \cos(\theta)^2\cdot 3\right)$$

It is going to substitute the results of these expressions in the expressions of the matrix terms D.8 and operate:

$$\mathbf{a_{11}} = -\frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)\cdot\sin(\theta) + \cos\left(\theta-\frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta-\frac{2\cdot\pi}{3}\right) + \cos\left(\theta+\frac{2\cdot\pi}{3}\right)\cdot\right.$$
$$\left.\cdot\sin\left(\theta+\frac{2\cdot\pi}{3}\right)\right) = -\frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)\cdot\sin(\theta) + \left(\frac{1}{2}\cdot\left(-\cos(\theta) + \sin(\theta)\cdot\sqrt{3}\right)\right)\cdot\right.$$
$$\cdot\left(-\frac{1}{2}\cdot\left(\sin(\theta) + \cos(\theta)\cdot\sqrt{3}\right)\right) + \left(-\frac{1}{2}\cdot\left(\cos(\theta) + \sin(\theta)\cdot\sqrt{3}\right)\right)\cdot$$
$$\left.\cdot\left(\frac{1}{2}\cdot\left(-\sin(\theta) + \cos(\theta)\cdot\sqrt{3}\right)\right)\right) = -\frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)\cdot\sin(\theta) + \frac{\cos(\theta)\cdot\sin(\theta)}{4} + \right.$$
$$+\frac{\cos(\theta)^2\cdot\sqrt{3}}{4} - \frac{\sin(\theta)^2\cdot\sqrt{3}}{4} - \frac{3\cdot\cos(\theta)\cdot\sin(\theta)}{4} + \frac{\cos(\theta)\cdot\sin(\theta)}{4} - \frac{\cos(\theta)^2\cdot\sqrt{3}}{4} +$$
$$\left.+\frac{\sin(\theta)^2\cdot\sqrt{3}}{4} - \frac{3\cdot\cos(\theta)\cdot\sin(\theta)}{4}\right) = \mathbf{0}$$

$$\mathbf{a_{12}} = \frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)^2 + \cos\left(\theta-\frac{2\cdot\pi}{3}\right)^2 + \cos\left(\theta+\frac{2\cdot\pi}{3}\right)^2\right) = \frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)^2 + \right.$$
$$+\frac{\cos(\theta)^2}{4} - \frac{2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3}}{4} + \frac{3\cdot\sin(\theta)^2}{4} + \frac{\cos(\theta)^2}{4} + \frac{2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3}}{4} +$$
$$\left.+\frac{3\cdot\sin(\theta)^2}{4}\right) = \frac{2}{3}\cdot\frac{3}{2}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)^2 + \sin(\theta)^2\right) = \mathbf{l_l\cdot\omega}$$

The useful property is: $\left(\cos(\theta)^2 + \sin(\theta)^2\right) = 1$

$$\mathbf{a_{21}} = -\frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\sin(\theta)^2 + \sin\left(\theta-\frac{2\cdot\pi}{3}\right)^2 + \sin\left(\theta+\frac{2\cdot\pi}{3}\right)^2\right) = -\frac{2}{3}\cdot l_l\cdot\omega\cdot$$
$$\cdot\left(\sin(\theta)^2 + \frac{\sin(\theta)^2}{4} + \frac{2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3}}{4} + \frac{3\cdot\cos(\theta)^2}{4} + \frac{\sin(\theta)^2}{4} - \right.$$
$$\left.-\frac{2\cdot\cos(\theta)\cdot\sin(\theta)\cdot\sqrt{3}}{4} + \frac{3\cdot\cos(\theta)^2}{4}\right) = -\frac{2}{3}\cdot\frac{3}{2}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)^2 + \sin(\theta)^2\right) = -\mathbf{l_l\cdot\omega}$$

$$\mathbf{a_{22}} = \frac{2}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta)\cdot\sin(\theta) + \cos\left(\theta-\frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta-\frac{2\cdot\pi}{3}\right) + \right.$$
$$\left.+\cos\left(\theta+\frac{2\cdot\pi}{3}\right)\cdot\sin\left(\theta+\frac{2\cdot\pi}{3}\right)\right) = -a_{11} = \mathbf{0}$$

$$\mathbf{a_{31}} = -\frac{1}{3}\cdot l_l\cdot\omega\cdot\left(\sin(\theta) + \sin\left(\theta-\frac{2\cdot\pi}{3}\right) + \sin\left(\theta+\frac{2\cdot\pi}{3}\right)\right) =$$
$$= -\frac{1}{3}\cdot l_l\cdot\omega\cdot\left(\sin(\theta) - \frac{1}{2}\cdot\left(\sin(\theta) + \cos(\theta)\cdot\sqrt{3}\right) + \frac{1}{2}\cdot\left(-\sin(\theta) + \cos(\theta)\cdot\sqrt{3}\right)\right) = \mathbf{0}$$

$$\mathbf{a_{32}} = \frac{1}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta) + \cos\left(\theta-\frac{2\cdot\pi}{3}\right) + \cos\left(\theta+\frac{2\cdot\pi}{3}\right)\right) =$$

$$= \frac{1}{3}\cdot l_l\cdot\omega\cdot\left(\cos(\theta) + \frac{1}{2}\cdot\left(-\cos(\theta) + \sin(\theta)\cdot\sqrt{3}\right) - \frac{1}{2}\cdot\left(\cos(\theta) + \sin(\theta)\cdot\sqrt{3}\right)\right) = \mathbf{0}$$

The matrix D.8 obtained is:

$$\begin{bmatrix} 0 & l_l\cdot\omega & 0 \\ -l_l\cdot\omega & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{D.9}$$

The resolution of the system D.1, substituting D.3 and D.9, is the following:

$$v_{zqd0} - v_{lqd0} = \begin{bmatrix} r_l & 0 & 0 \\ 0 & r_l & 0 \\ 0 & 0 & r_l \end{bmatrix} i_{qd0} + \begin{bmatrix} 0 & l_l\cdot\omega & 0 \\ -l_l\cdot\omega & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} i_{qd0} + \begin{bmatrix} l_l & 0 & 0 \\ 0 & l_l & 0 \\ 0 & 0 & l_l \end{bmatrix} \frac{di_{qd0}}{dt} \tag{D.10}$$

After that, eliminating the zero sequence (3rd component) and adding up the terms of i_{qd0}, the final coupled system D.2 is obtained:

$$\begin{bmatrix} v_{zq} \\ v_{zd} \end{bmatrix} - \begin{bmatrix} v_{lq} \\ v_{ld} \end{bmatrix} = \begin{bmatrix} r_l & l_l\cdot\omega \\ -l_l\cdot\omega & r_l \end{bmatrix} \begin{bmatrix} i_q \\ i_d \end{bmatrix} + \begin{bmatrix} l_l & 0 \\ 0 & l_l \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_q \\ i_d \end{bmatrix} \tag{D.11}$$

D.2 Active power expressions

The more common expression of the active power in a three phase system is the following:

$$P = 3\cdot V_{neutral-phase}\cdot I_{RMS} = 3\cdot V_{fn}\cdot I_{RMS} \tag{D.12}$$

This expression is adding up the power of each phase. Furthermore, the active power expression presented has more equivalences:

$$P = 3\cdot V_{fn}\cdot I_{RMS} = 3\cdot\frac{U_{ab}}{\sqrt{3}}\cdot I_{RMS} = \sqrt{3}\cdot U_{ab}\cdot I_{RMS} \tag{D.13}$$

It must be taken into account the following:

$$v_{zq} = V_{fn}\cdot\sqrt{2} \tag{D.14}$$

$$I_{peak} = I_{RMS}\cdot\sqrt{2} \tag{D.15}$$

With these expressions, it is possible to obtain the next relationship, when $v_{zd} = 0$:

$$P = 3\cdot V_{fn}\cdot I_{RMS} = 3\cdot\frac{v_{zq}}{\sqrt{2}}\frac{I_{peak}}{\sqrt{2}} = \frac{3}{2}\cdot v_{zq}\cdot I_{peak} = \frac{3}{2}\cdot v_{zq}\cdot i_q \tag{D.16}$$

Annex E

Matlab-Simulink®

E.1 Simulation of the VSC converter with the DC side modelled as a voltage source

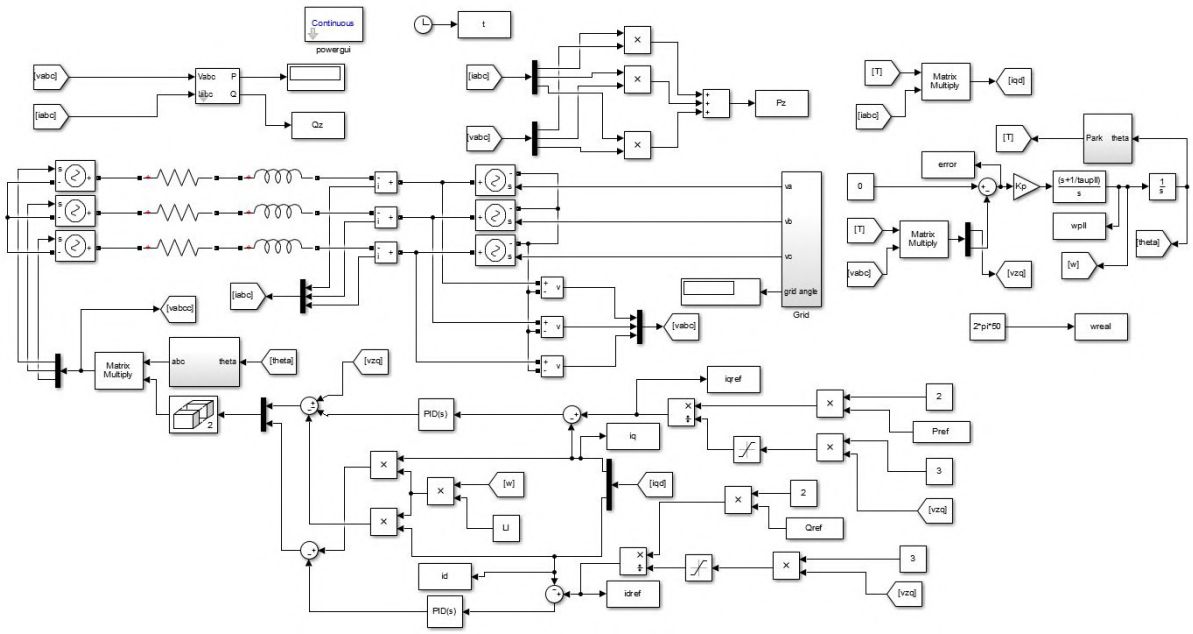

Figure E.1: General scheme in Simulink of VSC with the DC side modelled as a voltage source

In the next subsections, it is presented the modeling of the VSC control parts separately and the modeling of the grid. Also, other blocks used in calculations are presented.

E.1.1 Modeling of the VSC converter

Here it is presented the VSC converter without its control parts.

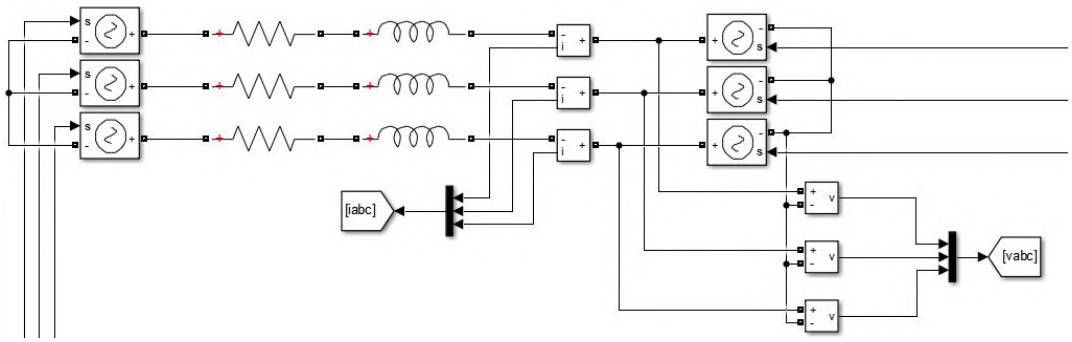

Figure E.2: Modeling of the VSC converter without its control parts

E.1.2 Phase Locked-Loop (PLL)

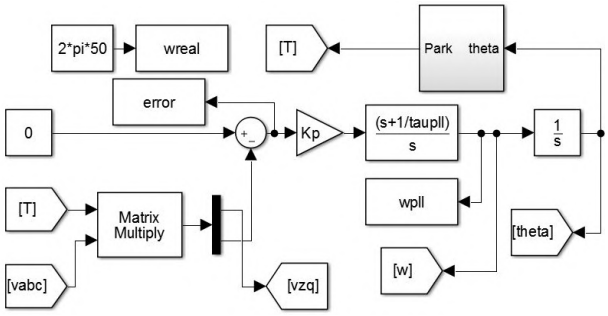

Figure E.3: Modeling of the Phase Locked-Loop

E.1.3 Park Transformation

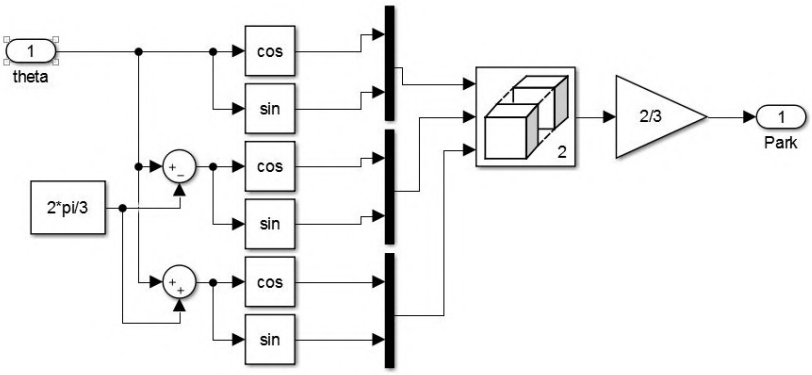

Figure E.4: Matrix of Park transformation

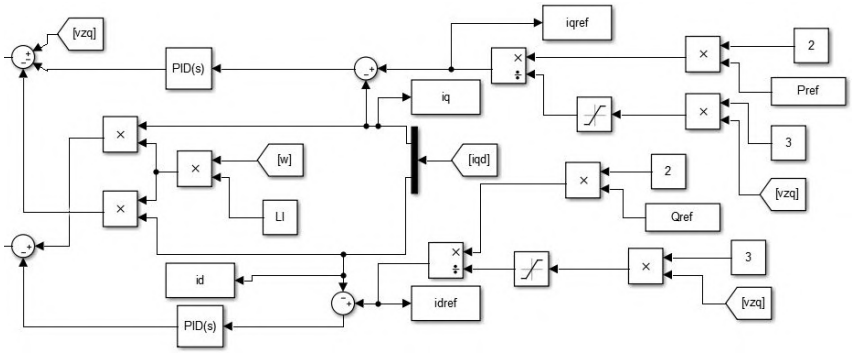

Figure E.5: Modeling of the current loop

E.1.4 Current loop

E.1.5 Calculation of iqd currents for the current loop

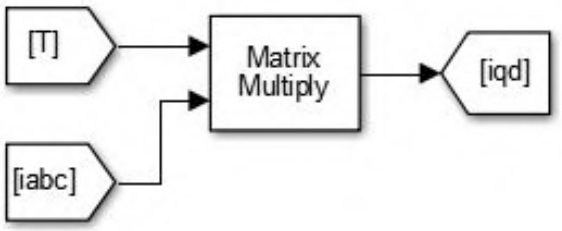

Figure E.6: Calculation of iqd currents

E.1.6 Module between the converter and the current loop

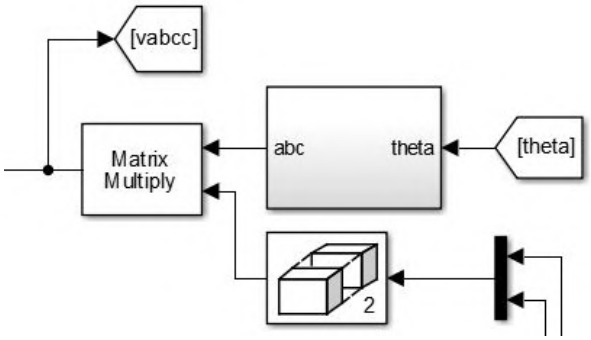

Figure E.7: Modeling of the module

E.1.7 The anti-transformed of Park

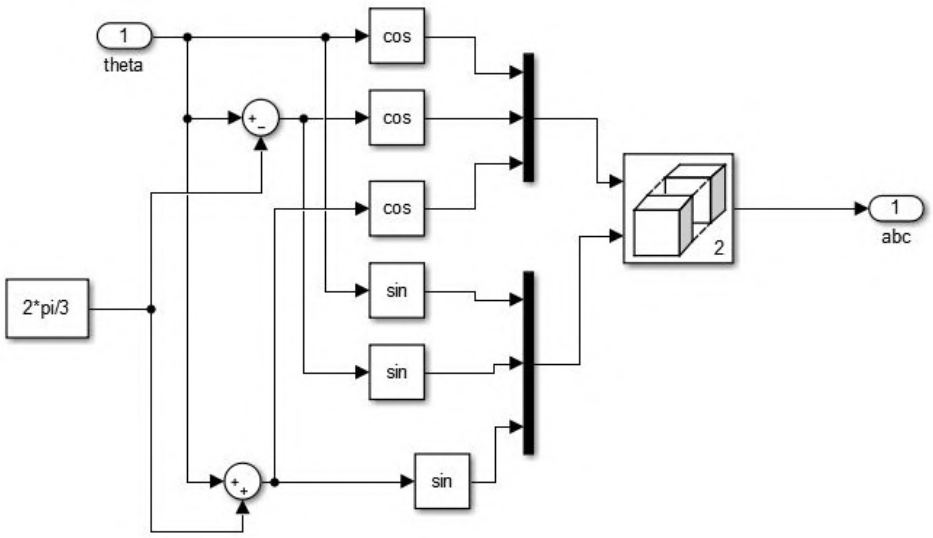

Figure E.8: The matrix of the anti-transformed Park

E.1.8 Calculation of the active power

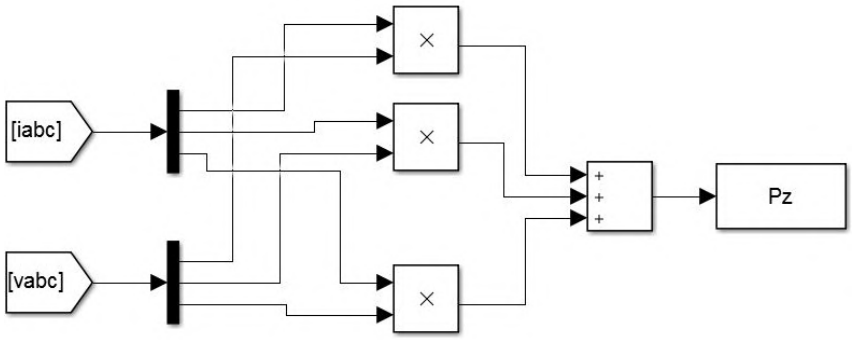

Figure E.9: Active power

E.1.9 Calculation of the reactive power

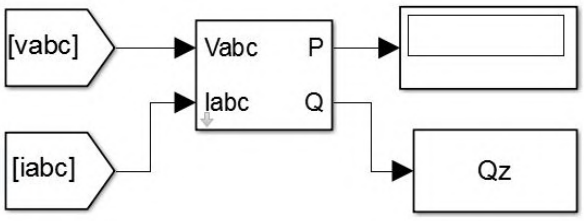

Figure E.10: Reactive power

E.1.10 Modeling of the grid

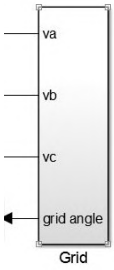

Figure E.11: Block of the grid

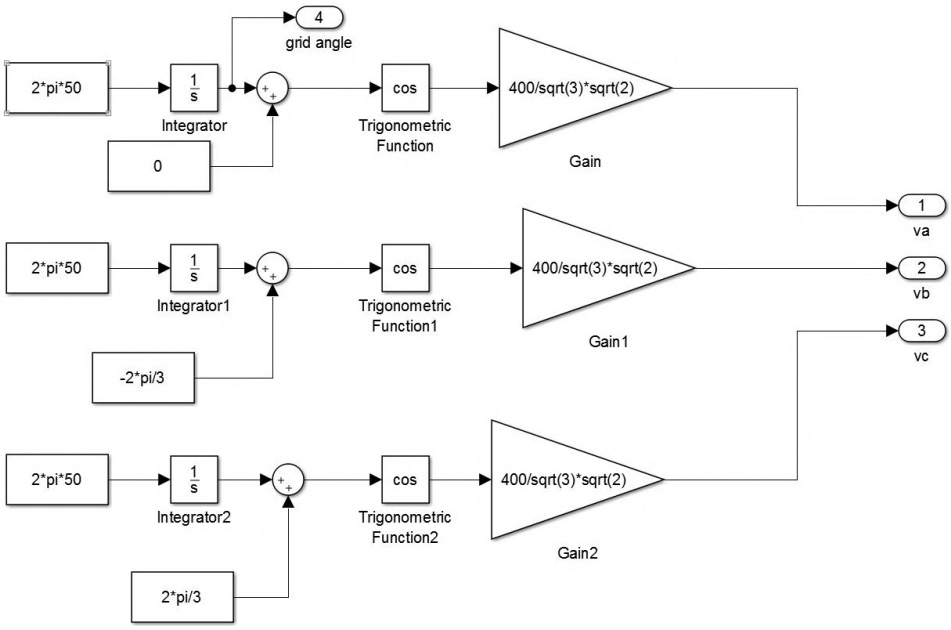

Figure E.12: Modeling of the grid. Inside of the block of the grid

The gain block represents the peak voltage of the phase-neutral voltage. These voltages of a trifasic system are:

$$v_a = \cos(\omega \cdot t + 0) \cdot \frac{400}{\sqrt{3}} \cdot \sqrt{2} \tag{E.1}$$

$$v_b = \cos\left(\omega \cdot t - 2 \cdot \frac{\pi}{3}\right) \cdot \frac{400}{\sqrt{3}} \cdot \sqrt{2} \tag{E.2}$$

$$v_c = \cos\left(\omega \cdot t + 2 \cdot \frac{\pi}{3}\right) \cdot \frac{400}{\sqrt{3}} \cdot \sqrt{2} \tag{E.3}$$

where ω is the velocity angular of the grid and in this case is $\omega = 2 \cdot \pi \cdot 50$ (50 Hz is the frequency) and the angle of the grid is $\theta = \omega \cdot t$ where t is the simulation's time. The integral of ω is θ, therefore in Laplace's domain it is necessary an integrator $1/s$.

E.2 Simulation of the VSC converter with the DC side modelled as a current source and a capacitor

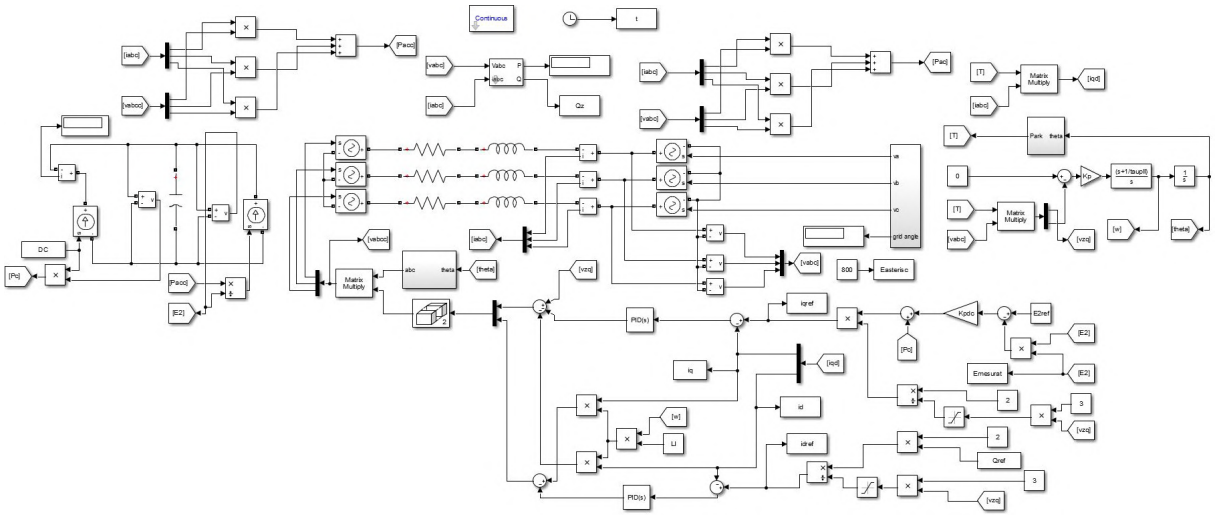

Figure E.13: General scheme in Simulink of VSC with the DC side modelled as a current source and a capacitor

All the VSC control parts are the same that in the section before. Therefore, in continuation only is presented the modeling of the DC side and the DC voltage regulator that it is not in the section before.

E.2.1 Modeling of the DC side

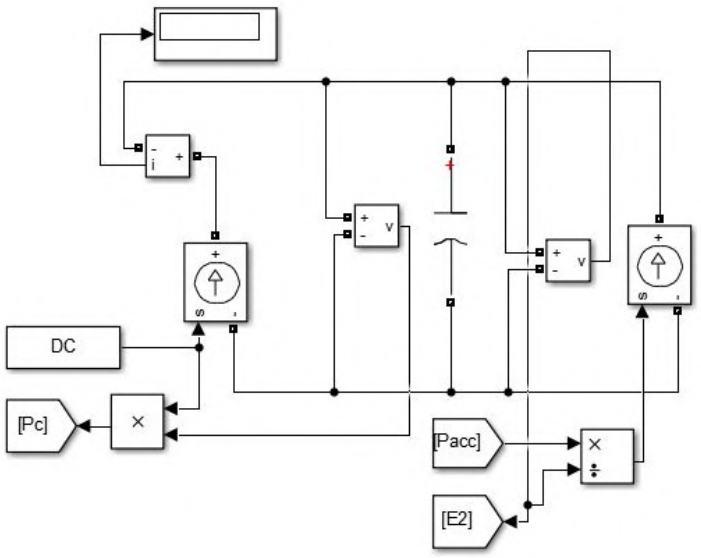

Figure E.14: Modeling of the DC side

E.2.2 DC voltage regulator

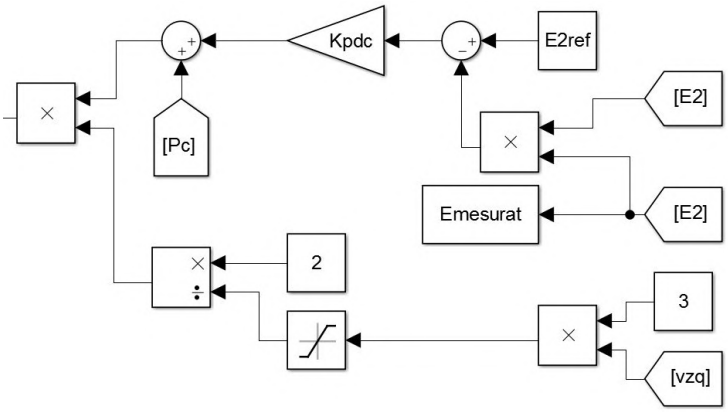

Figure E.15: DC voltage regulator

E.3 Simulation of the multi-terminal HVDC grid

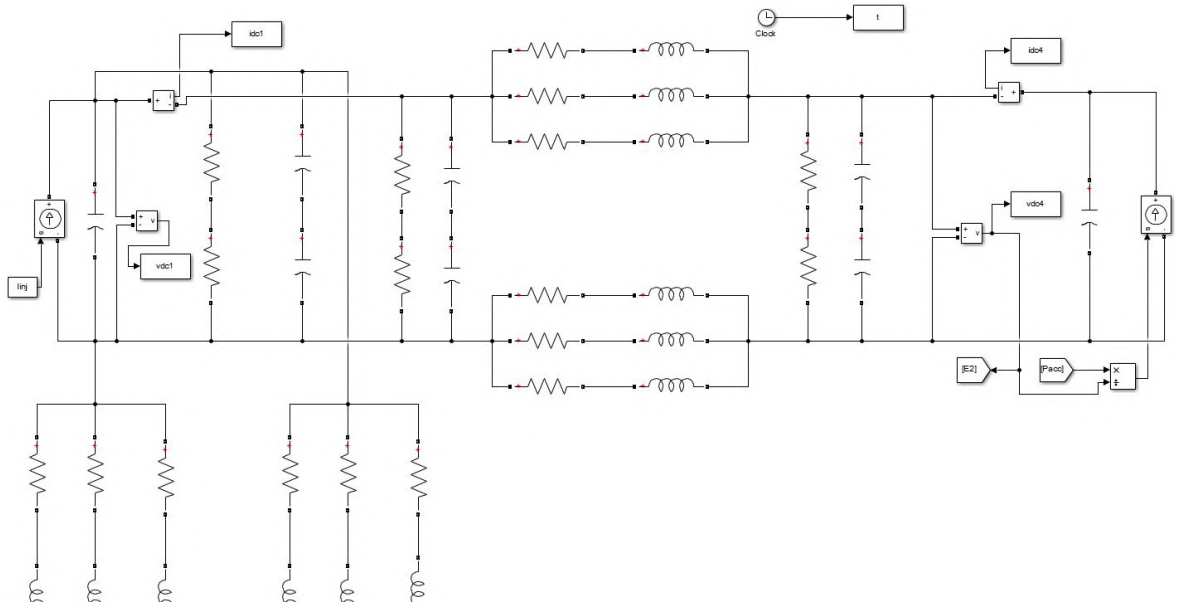

Figure E.16: Modeling of the multi-terminal HVDC grid part 1

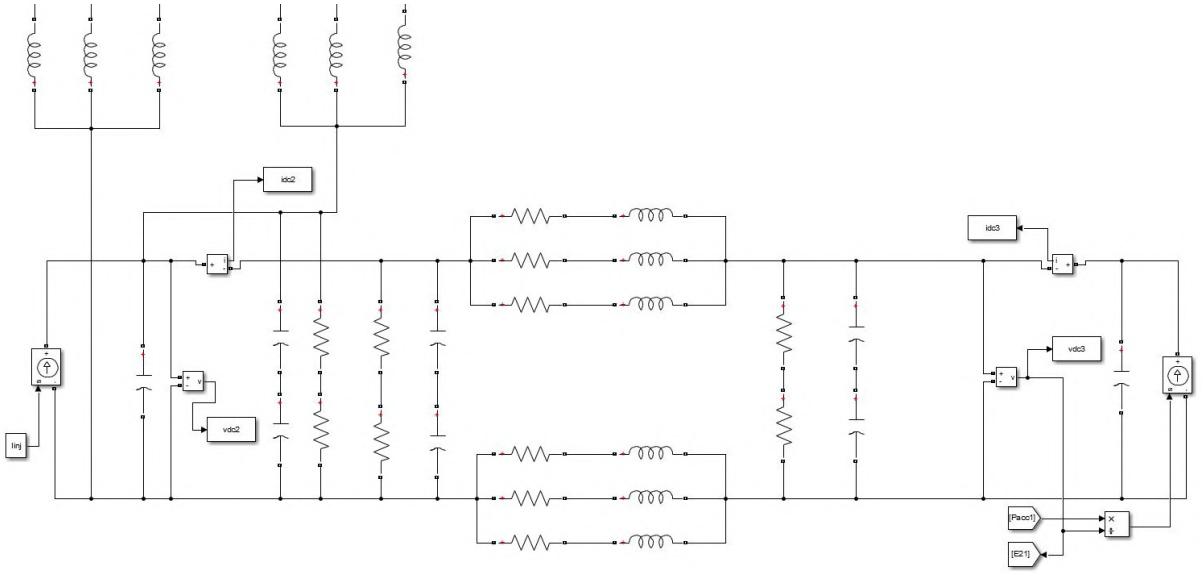

Figure E.17: Modeling of the multi-terminal HVDC grid part 2

E.3.1 DC voltage regulator of the multi-terminal HVDC grid

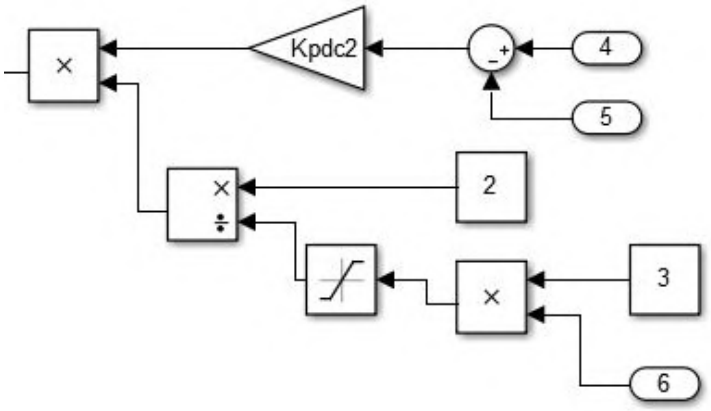

Figure E.18: DC voltage regulator of the multi-terminal HVDC grid

E.4 Blocks used in the modelings

Continuous powergui

Figure E.19: Continuous powergui

This block serves to define the conditions of the simulation. Without this block it is impossible to simulate and when the button *Run* is clicked, the simulation does not start. It is found in the library *Simscape/Power Systems/Specialized Technology/Fundamental blocks*.

Clock

Figure E.20: Clock

This block displays and provides simulation time. The Clock block outputs the current simulation time at each simulation step and it is useful for other blocks that need the simulation time. It is found in the library *Simulink/Sources*.

Controlled voltage source

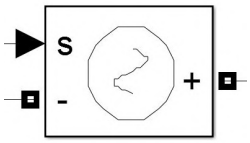

Figure E.21: Controlled voltage source

The Controlled Voltage Source block converts the Simulink input signal into an equivalent voltage source. The generated voltage is driven by the input signal of the block. It is possible to initialize the Controlled Voltage Source block with a specific AC or DC voltage. To start the simulation in steady state, the Simulink input must be connected to a signal starting as a sinusoidal or DC waveform corresponding to the initial values. It is found in the library *Simscape/Power Systems/Specialized Technology/Fundamental blocks/Electrical sources*.

Voltage measurement

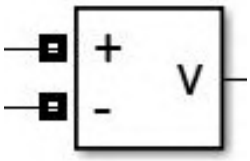

Figure E.22: Voltage measurement

The Voltage Measurement block measures the instantaneous voltage between two electric nodes. The output provides a Simulink signal that can be used by other Simulink blocks. It is found in the library *Simscape/Power Systems/Specialized Technology/Fundamental blocks/Measurements*.

Current measurement

The Current Measurement block is used to measure the instantaneous current flowing in any electrical block or connection line. The Simulink output provides a Simulink signal that can be

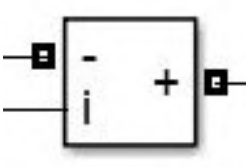

Figure E.23: Current measurement

used by other Simulink blocks. It is found in the library *Simscape/Power Systems/Specialized Technology/Fundamental blocks/Measurements*.

To workspace

Figure E.24: To workspace

The To Workspace block inputs a signal and writes the signal data to a workspace. During the simulation, the block writes data to an internal buffer. When the simulation is completed or paused, that data is written to the workspace. Data is not available until the simulation is stopped or paused. The example of the Figure E.24 is the voltage in the offshore wind farm DC side written in workspace by the software with the calculations. This block is found in the library *Simulink/Sinks*.

From workspace

Figure E.25: From workspace

The From Workspace block reads signal data from a workspace and outputs the data as a signal. The example of the Figure E.25 is the active power in function of the time written in workspace and this data is read by the software to output a signal. This block is found in the library *Simulink/Sources*.

Goto

The *Goto* block passes its input to its corresponding *From* blocks. The input can be a real- or complex-valued signal or vector of any data type. *From* and *Goto* blocks allow you to pass a signal from one block to another without actually connecting them. These blocks are very useful to reduce the space of the scheme and to avoid to connect a lot of blocks with a high quantity of lines. The *Goto* block is found in the library *Simulink/Signal Routing*.

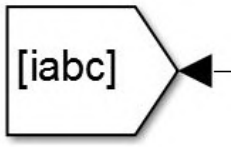

Figure E.26: Goto

From

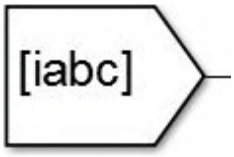

Figure E.27: From

The From block accepts a signal from a corresponding Goto block, then passes it as output. The data type of the output is the same as that of the input from the Goto block. From and Goto blocks allow you to pass a signal from one block to another without actually connecting them. To associate a Goto block with a From block, enter the Goto block's tag in the Goto Tag parameter. The *From* block is found in the library *Simulink/Signal Routing*.

Matrix concatenate

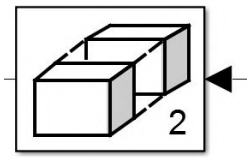

Figure E.28: Concatenation block

The Concatenate block concatenates the signals at its inputs to create an output signal whose elements reside in contiguous locations in memory. The Concatenate block operates in either vector or multidimensional array concatenation mode, depending on the setting of its Mode parameter. In either case, the block concatenates the inputs from the top to bottom, or left to right, input ports.

In vector mode, all input signals must be either vectors or row vectors [1xM matrices] or column vectors [Mx1 matrices] or a combination of vectors and either row or column vectors. The output is a vector if all inputs are vectors. The output is a row or column vector if any of the inputs are row or column vectors, respectively.

Multidimensional array mode accepts vectors and arrays of any size. It assumes that the trailing dimensions are all ones for input signals with lower dimensionality. For example, if the output is 4-D and the input is [2x3] (2-D) this block treats the input as [2x3x1x1]. The output is always an array. The block's Concatenate dimension parameter allows to specify the output dimension along which the block concatenates its input arrays.

This block is found in the library *Simulink/Math Operations*.

Mux block

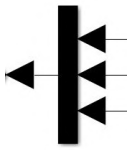

Figure E.29: Mux block

The Mux block combines its inputs into a single vector output. An input can be a scalar or vector signal. All inputs must be of the same data type and numeric type. The elements of the vector output signal take their order from the top to bottom, or left to right, input port signals. This block is found in the library *Simulink/Signal Routing*.

Zero pole block

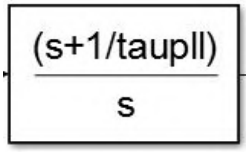

Figure E.30: Zero pole block

The Zero-Pole block models a system that is defined with the zeros, poles, and gain of a Laplace-domain transfer function. This block can model single-input single output (SISO) and single-input multiple-output (SIMO) systems. The example of the Figure E.30 has the following inputs: the zero is $-1/\tau_{PLL}$, there are not poles and the gain is 1. This block is found in the library *Simulink/Continuous*.

PID block

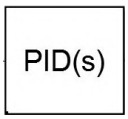

Figure E.31: PID block

The PID Controller is formed by the proportional, integral, and derivative gain parameters. A first-order pole filters the derivative action. The user can introduce these 3 gains manually. This block is found in the library *Simulink/Continuous*.

Saturation block

The Saturation block imposes upper and lower limits on an input signal. In the schemes this block have been used to avoid divide by zero because in the initial states the voltages increases from zero. This block is found in the library *Simulink/Discontinuities*.

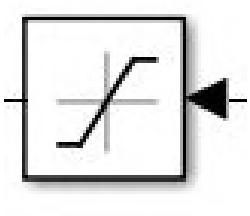

Figure E.32: Saturation block

Power (3ph, Instantaneous) block

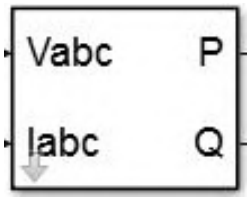

Figure E.33: three-phase instantaneous active and reactive powers

The Power (3ph, Instantaneous) block computes the three-phase instantaneous active power P (in watts) and reactive power Q (in VAr) associated with a periodic set of three-phase voltages and currents. These formulas are used to perform the calculations:

$$P = V_a \cdot I_a + V_b \cdot I_b + V_c \cdot I_c \tag{E.4}$$

$$Q = \frac{1}{\sqrt{3}} \left[(V_b - V_c) \cdot I_a + (V_c - V_a) \cdot I_b + (V_a - V_b) \cdot I_c \right] \tag{E.5}$$

With these formulas, a current flowing into an RL circuit produces a positive P and a positive Q. The computed instantaneous reactive power is accurate only for balanced and harmonic-free three-phase voltages and currents. The Power (3ph, Instantaneous) block is found in the library *Simscape/Power Systems/Specialized Technology/Control & Measurements/Measurements*.

The rest blocks employed in the schemes are trivial such as the sum, the division, the product, the substraction and the multiplication of matrices.

Annex F

The code in Matlab®

F.1 Code of the simulation of the VSC converter with the DC side modelled as a voltage source

```
% File Name: Parameters_DC_Side_Voltage_Source.m
% VSC converter with the DC side modelled as a voltage source
clear all
close all
clc

% Parameters
tau = 0.01;
taupll = 0.0045;
Ll = 0.0054;
rl = 0.5;
Kp = 1.36;

% Data of reactive power reference
Qref.time = [0; 0.3; 0.3; 0.5; 0.5; 0.8; 0.8; 0.9; 0.9; 1];
Qref.signals.values = [0; 0; -5000; -5000; 0; 0; 2000; 2000; -7000;
-7000];

% Data of active power reference
Pref.time = [0; 0.3; 0.3; 0.5; 0.5; 0.8; 0.8; 0.9; 0.9; 1];
Pref.signals.values = [-3000; -3000; -6000; -6000; -1000; -1000;
-7000; -7000; -7000; -7000];

% Simulation and plots of different electric measures
% Simulation time
tsimul = 1;

% sim simulates the Simulink File
sim Simulink_DC_Side_Voltage_Source
```

```
% Plot of reactive power reference and reactive power
figure(1);
plot(Qref.time, Qref.signals.values, t, Qz, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Reactive power [VAr]', 'FontSize', 14);
legend('Q_z^*', 'Q_z');

% Plot of active power reference and active power
figure(2);
plot(Pref.time, Pref.signals.values, t, Pz, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Active power [W]', 'FontSize', 14);
legend('P_z^*', 'P_z');

% Plot of current q reference and current q
figure(3);
plot(t, iqref, t, iq, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Current [A]', 'FontSize', 14);
legend('I_q^*', 'I_q');

% Plot of current d reference and current d
figure(4);
plot(t, idref, t, id, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Current [A]', 'FontSize', 14);
legend('I_d^*', 'I_d');

% Plot of the tracking of the PLL
figure(5);
subplot(2,1,1);
plot(t, wreal, t, wpll, 'LineWidth', 2);
grid on;
xlim([0 0.1]);
xlabel('Time [s]', 'FontSize', 14);
ylabel('Angular velocity [rad/s]', 'FontSize', 10);
legend('w_P_L_L', 'w_r_e_a_l');

% Plot of the PLL error
subplot(2,1,2);
plot(t, error, 'LineWidth', 2);
grid on;
xlim([0 0.1]);
xlabel('Time [s]', 'FontSize', 14);
ylabel('PLL \theta error [rad]', 'FontSize', 10);
```

F.2 Code of the simulation of the VSC converter with the DC side modelled as a current source and a capacitor

```
% File Name: Parameters_DC_Side_Current_Source_Capacitor.m
% VSC converter with the DC side modelled as a current source and
% a capacitor
clear all
close all
clc

% Parameters
tau = 0.001;
taupll = 0.0045;
Kp = 1.36;
Ll = 0.0054;
rl = 0.5;
E2ref = 800^2;
Kpdc = 10;

% Data of reactive power reference
Qref.time = [0; 0.3; 0.3; 0.5; 0.5; 0.8; 0.8; 0.9; 0.9; 1];
Qref.signals.values = [0; 0; 0; 0; -5000; -5000; -5000; -5000; 0; 0];

% Data of Direct Current injected
DC.time = [0; 0.3; 0.3; 0.5; 0.5; 0.8; 0.8; 0.9; 0.9; 1];
DC.signals.values = [3; 3; 10; 10; 5; 5; 7.5; 7.5; 10; 10];

% Simulation and plots of different electric measures
% Simulation time
tsimul = 1;

% sim simulates the Simulink File
sim Simulink_DC_Side_Current_Source_Capacitor

% Plot of reactive power reference and reactive power
figure(1);
plot(Qref.time, Qref.signals.values, t, Qz, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Reactive power [VAr]', 'FontSize', 14);
legend('Q_z^*', 'Q_z')

% Plot of current q reference and current q
figure(2);
plot(t, iqref, t, iq, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Current [A]', 'FontSize', 14);
legend('I_q^*', 'I_q')
```

```
% Plot of current d reference and current d
figure(3);
plot(t, idref, t, id, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Current [A]', 'FontSize', 14);
legend('I_d^*', 'I_d')

% Plot of DC bus voltage reference and DC bus voltage
figure(4);
plot(t, Easterisc, t, Emesurat, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('DC bus voltage [V]', 'FontSize', 14);
legend('E^*', 'E')
```

F.3 Code of the simulation of the multi-terminal HVDC grid. Case 1: Equal proportional gains

```
% File Name: Parameters_multiterminal_HVDC_grid.m
% Simulation of a multi-terminal HVDC grid
clear all
close all
clc

% Parameters
tau = 0.001;
taupll = 0.0045;
Kp = 0.0017;
rl = 3.072;
Ll = 0.1956;
E2ref = 640000;
Vdc = 640000;
Uab = 320000;
r1 = 0.1265;
r2 = 0.1504;
r3 = 0.0178;
c = 0.1616*(10^-6);
l1 = 0.2644*(10^-3);
l2 = 7.2865*(10^-3);
l3 = 3.6198*(10^-3);
g = 0.1015*(10^-6);
Rg = (1/g);
Cconv = 1.5*(10^-4);
d1 = 230;
d2 = 75;
d3 = 217;
```

```
Qref = 0;
Pinj = 500*(10^6);

% Profile current injected
Iinj.time = [0; 1; 1; 2];
Iinj.signals.values = [0; 0; Pinj/Vdc; Pinj/Vdc];
figure(100);
plot(Iinj.time, Iinj.signals.values, 'LineWidth', 2);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('Current injected [A]', 'FontSize', 14);

% Limit values
vdcrefmax = (((5/100)*Vdc) + Vdc)/1000;
iqrefmax = 1340;
iabcrefmax = 1340;
iabcrefmax1 = -1340;
idrefmax = 0;
idcrefmax = 820;
vlrefmax = round(((5/100)*(((Uab/sqrt(3))*sqrt(2))/1000))
+(((Uab/sqrt(3))*sqrt(2))/1000));
vlrefmax1 = -(round(((5/100)*(((Uab/sqrt(3))*sqrt(2))/1000))
+(((Uab/sqrt(3))*sqrt(2))/1000)));
vlqrefmax = 274;

% Simulations: Kpdc changes
tsimul = 2;
n = 0; % Simulation counter
for Kpdc = [55000 : 9500 : 150000]
    n = n + 1;

    % List of colors to plot (One color for each simulation)
    C = { [0.8500, 0.3250, 0.0980], 'b', [0.4 0.3 0.2], 'r',
    [0.7 0.7 0.7], 'g', 'y', 'c', 'm', 'k', [0.5 0.1 1]};

    % It simulates the Simulink File
    sim Simulink_multiterminal_HVDC_grid

    % Data extracted of Simulink saved in matrices
    kpdc_matrix(:,n) = Kpdc;
    vdc1_matrix(:,n) = vdc1;
    vdc2_matrix(:,n) = vdc2;
    vdc3_matrix(:,n) = vdc3;
    vdc4_matrix(:,n) = vdc4;
    iq1_matrix(:,n) = iq1;
    id1_matrix(:,n) = id1;
    ia1_matrix(:,n) = ia1;
    ib1_matrix(:,n) = ib1;
    ic1_matrix(:,n) = ic1;
```

```
vlq1_matrix(:,n) = vlq1;
vld1_matrix(:,n) = vld1;
vla1_matrix(:,n) = vla1;
vlb1_matrix(:,n) = vlb1;
vlc1_matrix(:,n) = vlc1;
iq2_matrix(:,n) = iq2;
id2_matrix(:,n) = id2;
ia2_matrix(:,n) = ia2;
ib2_matrix(:,n) = ib2;
ic2_matrix(:,n) = ic2;
vlq2_matrix(:,n) = vlq2;
vld2_matrix(:,n) = vld2;
vla2_matrix(:,n) = vla2;
vlb2_matrix(:,n) = vlb2;
vlc2_matrix(:,n) = vlc2;
idc1_matrix(:,n) = idc1;
idc2_matrix(:,n) = idc2;
idc3_matrix(:,n) = idc3;
idc4_matrix(:,n) = idc4;


% The num2str function converts
% numbers to their string representations.
% Variables to show in the legend
a = ['K_p_D_C = ', num2str(Kpdc)];
bvdc = ['V_D_C_m_a_x = ', num2str(vdcrefmax), ' kV'];
ciq = ['i_q_m_a_x = ', num2str(iqrefmax), ' A'];
did = ['i_d_m_a_x = ', num2str(idrefmax), ' A'];
eidc = ['I_D_C_m_a_x = ', num2str(idcrefmax), ' A'];
vlpeak = ['v_l_a_b_c_m_a_x = ', num2str(vlrefmax), ' kV'];
vlpeak1 = ['v_l_a_b_c_m_a_x = ', num2str(vlrefmax1), ' kV'];
iabcmax = ['i_a_b_c_m_a_x = ', num2str(iabcrefmax), ' A'];
iabcmax1 = ['i_a_b_c_m_a_x = ', num2str(iabcrefmax1), ' A'];
fvlq = ['v_l_q_m_a_x = ', num2str(vlqrefmax), ' kV'];

% Plots of the electrical measures in function of the Kpdc
% DynamicLegend serves to update the legend
hold on;

figure(1);
if n == 1
    hold on;
    plot(t, vdcmax/1000, 'DisplayName', bvdc,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vdc1/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
hold all;
```

```
xlim([0.8 2]); % Limits de la x
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('V_D_C_1 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(2);
if n == 1
    hold on;
    plot(t, vdcmax/1000, 'DisplayName', bvdc,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vdc2/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('V_D_C_2 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(3);
if n == 1
    hold on;
    plot(t, vdcmax/1000, 'DisplayName', bvdc,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vdc3/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('V_D_C_3 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(4);
if n == 1
    hold on;
    plot(t, vdcmax/1000, 'DisplayName', bvdc,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vdc4/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
```

```
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('V_D_C_4 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(5);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', ciq,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, abs(iq1), 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_q_1 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(6);
if n == 1
    hold on;
    plot(t, idmax, 'DisplayName', did,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, id1, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_d_1 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(7);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', iabcmax,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, iqmax1, 'DisplayName', iabcmax1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
```

```
plot(t, ia1, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_a_1 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(8);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', iabcmax,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, iqmax1, 'DisplayName', iabcmax1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, ib1, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_b_1 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(9);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', iabcmax,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, iqmax1, 'DisplayName', iabcmax1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, ic1, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_c_1 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');
```

```
figure(10);
if n == 1
    hold on;
    plot(t, vlqmax, 'DisplayName', fvlq,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vlq1/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_q_1 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(11);
plot(t, abs(vld1/1000), 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_d_1 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(12);
if n == 1
    hold on;
    plot(t, vlmax, 'DisplayName', vlpeak,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, vlmax1, 'DisplayName', vlpeak1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vla1/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_a_1 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(13);
if n == 1
    hold on;
```

```
    plot(t, vlmax, 'DisplayName', vlpeak,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, vlmax1, 'DisplayName', vlpeak1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vlb1/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_b_1 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(14);
if n == 1
    hold on;
    plot(t, vlmax, 'DisplayName', vlpeak,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, vlmax1, 'DisplayName', vlpeak1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vlc1/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_c_1 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(15);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', ciq,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, abs(iq2), 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
```

```
ylabel('i_q_2 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(16);
if n == 1
    hold on;
    plot(t, idmax, 'DisplayName', did,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, id2, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_d_2 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(17);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', iabcmax,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, iqmax1, 'DisplayName', iabcmax1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, ia2, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_a_2 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(18);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', iabcmax,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, iqmax1, 'DisplayName', iabcmax1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
```

```
    hold all;
end
plot(t, ib2, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_b_2 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(19);
if n == 1
    hold on;
    plot(t, iqmax, 'DisplayName', iabcmax,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, iqmax1, 'DisplayName', iabcmax1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, ic2, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('i_c_2 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(20);
if n == 1
    hold on;
    plot(t, vlqmax, 'DisplayName', fvlq,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vlq2/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_q_2 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(21);
plot(t, abs(vld2/1000), 'DisplayName', a,
```

```
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_d_2 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(22);
if n == 1
    hold on;
    plot(t, vlmax, 'DisplayName', vlpeak,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, vlmax1, 'DisplayName', vlpeak1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vla2/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_a_2 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(23);
if n == 1
    hold on;
    plot(t, vlmax, 'DisplayName', vlpeak,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, vlmax1, 'DisplayName', vlpeak1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vlb2/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_b_2 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(24);
```

```
if n == 1
    hold on;
    plot(t, vlmax, 'DisplayName', vlpeak,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
    hold on;
    plot(t, vlmax1, 'DisplayName', vlpeak1,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, vlc2/1000, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('v_l_c_2 [kV]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(25);
if n == 1
    hold on;
    plot(t, idcmax, 'DisplayName', eidc,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, idc1, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('I_D_C_1 [A]', 'FontSize', 14);
hold all;
legend('-DynamicLegend');

figure(26);
if n == 1
    hold on;
    plot(t, idcmax, 'DisplayName', eidc,
    'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
    hold all;
end
plot(t, idc2, 'DisplayName', a,
'color', C{n}, 'LineWidth', 2);
xlim([0.8 2]);
grid on;
xlabel('Time [s]', 'FontSize', 14);
ylabel('I_D_C_2 [A]', 'FontSize', 14);
hold all;
```

```
    legend('-DynamicLegend');

    figure(27);
    if n == 1
        hold on;
        plot(t, idcmax, 'DisplayName', eidc,
        'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
        hold all;
    end
    plot(t, abs(idc3), 'DisplayName', a,
    'color', C{n}, 'LineWidth', 2);
    xlim([0.8 2]);
    grid on;
    xlabel('Time [s]', 'FontSize', 14);
    ylabel('I_D_C_3 [A]', 'FontSize', 14);
    hold all;
    legend('-DynamicLegend');

    figure(28);
    if n == 1
        hold on;
        plot(t, idcmax, 'DisplayName', eidc,
        'color', [0.7, 0.8, 0.1], 'LineWidth', 2);
        hold all;
    end
    plot(t, abs(idc4), 'DisplayName', a,
    'color', C{n}, 'LineWidth', 2);
    xlim([0.8 2]);
    grid on;
    xlabel('Time [s]', 'FontSize', 14);
    ylabel('I_D_C_4 [A]', 'FontSize', 14);
    hold all;
    legend('-DynamicLegend');
end
```

F.4 Code of the simulation of the multi-terminal HVDC grid. Case 2: Different proportional gains

```
% File Name: Parameters_multiterminal_HVDC_grid_alphas.m
% Simulation of a multi-terminal HVDC grid
clear all
close all
clc

% Parameters
tau = 0.001;
taupll = 0.0045;
Kp = 0.0017;
```

```
rl = 3.072;
Ll = 0.1956;
E2ref = 640000;
Vdc = 640000;
Uab = 320000;
r1 = 0.1265;
r2 = 0.1504;
r3 = 0.0178;
c = 0.1616*(10^-6);
l1 = 0.2644*(10^-3);
l2 = 7.2865*(10^-3);
l3 = 3.6198*(10^-3);
g = 0.1015*(10^-6);
Rg = (1/g);
Cconv = 1.5*(10^-4);
d1 = 230;
d2 = 75;
d3 = 217;
Qref = 0;
Pinj = 500*(10^6);
% Profile current injected
Iinj.time = [0; 1; 1; 2];
Iinj.signals.values = [0; 0; Pinj/Vdc; Pinj/Vdc];

% Limit values
vdcrefmax = ((5/100)*Vdc) + Vdc;
iabcrefmax = 1340;
idcrefmax = 820;
vlrefmax = round((5/100)*((Uab/sqrt(3))*sqrt(2))
+((Uab/sqrt(3))*sqrt(2)));

% Simulations: Kpdc1 and Kpdc2 changes
tsimul = 2;
alpha = 0;
Kpdc = 4000;
Kpdc1 = Kpdc*alpha;
Kpdc2 = Kpdc*(1-alpha);
h1 = zeros(4,1);
h2 = zeros(4,1);
h3 = zeros(4,1);
h4 = zeros(4,1);
h5 = zeros(4,1);
h6 = zeros(4,1);
h7 = zeros(4,1);
h8 = zeros(4,1);
h9 = zeros(4,1);
h10 = zeros(4,1);
h11 = zeros(4,1);
h12 = zeros(4,1);
```

```
h13 = zeros(4,1);
h14 = zeros(4,1);
h15 = zeros(4,1);
h16 = zeros(4,1);
h17 = zeros(4,1);
h18 = zeros(4,1);
h19 = zeros(4,1);
h20 = zeros(4,1);

for Kpdc = [75000 : 7500 : 150000]

    % It simulates the Simulink File
    n = 0; % Simulation counter

    for alpha = [0: 0.1: 1]
        n = n + 1;

        sim Simulink_multiterminal_HVDC_grid_alphas

        % Kpdc1 i Kpdc2
        Kpdc1 = Kpdc*alpha;
        Kpdc2 = Kpdc*(1-alpha);

        % Data extracted of Simulink saved in matrices
        alpha_matrix(:,n) = alpha;
        Kpdc1_matrix(:,n) = Kpdc1;
        Kpdc2_matrix(:,n) = Kpdc2;
        vdc1_matrix(:,n) = vdc1;
        vdc2_matrix(:,n) = vdc2;
        vdc3_matrix(:,n) = vdc3;
        vdc4_matrix(:,n) = vdc4;
        ia1_matrix(:,n) = ia1;
        ib1_matrix(:,n) = ib1;
        ic1_matrix(:,n) = ic1;
        vla1_matrix(:,n) = vla1;
        vlb1_matrix(:,n) = vlb1;
        vlc1_matrix(:,n) = vlc1;
        ia2_matrix(:,n) = ia2;
        ib2_matrix(:,n) = ib2;
        ic2_matrix(:,n) = ic2;
        vla2_matrix(:,n) = vla2;
        vlb2_matrix(:,n) = vlb2;
        vlc2_matrix(:,n) = vlc2;
        idc1_matrix(:,n) = idc1;
        idc2_matrix(:,n) = idc2;
        idc3_matrix(:,n) = idc3;
        idc4_matrix(:,n) = idc4;
```

```
% Plots of the electrical measures in function of the Kpdc
% DynamicLegend serves to update the legend
hold on;

figure(1);
if  max(abs(vdc1_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc1_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h1(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc1_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc1_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h1(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc1_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc1_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h1(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc1_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc1_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h1(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('V_D_C_1', 'FontSize', 14);
hold all;


figure(2);
if  max(abs(vdc2_matrix(99996 : 129996, n))) < vdcrefmax
```

```
&& max(abs(vdc2_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h2(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc2_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc2_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h2(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc2_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc2_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h2(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc2_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc2_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h2(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('V_D_C_2', 'FontSize', 14);
hold all;


figure(3);
if  max(abs(vdc3_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc3_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h3(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
```

```
    hold all;
elseif max(abs(vdc3_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc3_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h3(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc3_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc3_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h3(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc3_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc3_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h3(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('V_D_C_3', 'FontSize', 14);
hold all;

figure(4);
if  max(abs(vdc4_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc4_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h4(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc4_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc4_matrix(129997 : 200001, n))) < vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
```

```
    h4(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc4_matrix(99996 : 129996, n))) < vdcrefmax
&& max(abs(vdc4_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h4(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vdc4_matrix(99996 : 129996, n))) > vdcrefmax
&& max(abs(vdc4_matrix(129997 : 200001, n))) > vdcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h4(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('V_D_C_4', 'FontSize', 14);
hold all;

figure(5);
if  max(abs(ia1_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ia1_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h5(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ia1_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ia1_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h5(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ia1_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ia1_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
```

```
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h5(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ia1_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ia1_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h5(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('i_a_1', 'FontSize', 14);
hold all;

figure(6);
if  max(abs(ib1_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ib1_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h6(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ib1_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ib1_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h6(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ib1_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ib1_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs', 'markersize',
    5, 'LineWidth', 2);
    h6(3) = plot(Kpdc1, Kpdc2, 'cs', 'markersize',
    5, 'LineWidth', 2);
    hold all;
elseif max(abs(ib1_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ib1_matrix(129997 : 200001, n))) > iabcrefmax
```

```
    hold on;
    plot(Kpdc1, Kpdc2, 'rx', 'markersize',
    5, 'LineWidth', 2);
    h6(4) = plot(Kpdc1, Kpdc2, 'rx', 'markersize',
    5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('i_b_1', 'FontSize', 14);
hold all;

figure(7);
if  max(abs(ic1_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ic1_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^', 'markersize',
    5, 'LineWidth', 2);
    h7(1) = plot(Kpdc1, Kpdc2, 'g^', 'markersize',
    5, 'LineWidth', 2);
    hold all;
elseif max(abs(ic1_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ic1_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h7(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ic1_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ic1_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h7(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ic1_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ic1_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h7(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
```

```
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('i_c_1', 'FontSize', 14);
hold all;

figure(8);
if  max(abs(vla1_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vla1_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h8(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vla1_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vla1_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h8(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vla1_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vla1_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h8(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vla1_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vla1_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h8(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('v_l_a_1', 'FontSize', 14);
hold all;

figure(9);
```

```
if  max(abs(vlb1_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlb1_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h9(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlb1_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlb1_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h9(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlb1_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlb1_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h9(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlb1_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlb1_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h9(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('v_l_b_1', 'FontSize', 14);
hold all;

figure(10);
if  max(abs(vlc1_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlc1_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h10(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
```

```
    hold all;
elseif max(abs(vlc1_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlc1_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h10(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlc1_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlc1_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h10(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlc1_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlc1_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h10(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('v_l_c_1', 'FontSize', 14);
hold all;

figure(11);
if  max(abs(ia2_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ia2_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h11(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ia2_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ia2_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
```

```
    h11(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ia2_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ia2_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h11(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ia2_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ia2_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h11(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('i_a_2', 'FontSize', 14);
hold all;

figure(12);
if  max(abs(ib2_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ib2_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h12(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ib2_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ib2_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h12(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ib2_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ib2_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
```

```
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h12(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ib2_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ib2_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h12(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('i_b_2', 'FontSize', 14);
hold all;

figure(13);
if  max(abs(ic2_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ic2_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h13(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ic2_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ic2_matrix(129997 : 200001, n))) < iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h13(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ic2_matrix(99996 : 129996, n))) < iabcrefmax
&& max(abs(ic2_matrix(129997 : 200001, n))) > iabcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h13(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(ic2_matrix(99996 : 129996, n))) > iabcrefmax
&& max(abs(ic2_matrix(129997 : 200001, n))) > iabcrefmax
```

```
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h13(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('i_c_2', 'FontSize', 14);
hold all;

figure(14);
if  max(abs(vla2_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vla2_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h14(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vla2_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vla2_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h14(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vla2_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vla2_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h14(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vla2_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vla2_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h14(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
```

```
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('v_l_a_2', 'FontSize', 14);
hold all;

figure(15);
if  max(abs(vlb2_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlb2_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h15(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlb2_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlb2_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h15(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlb2_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlb2_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h15(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlb2_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlb2_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h15(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('v_l_b_2', 'FontSize', 14);
hold all;

figure(16);
```

```
if  max(abs(vlc2_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlc2_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h16(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlc2_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlc2_matrix(129997 : 200001, n))) < vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h16(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlc2_matrix(99996 : 129996, n))) < vlrefmax
&& max(abs(vlc2_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h16(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(vlc2_matrix(99996 : 129996, n))) > vlrefmax
&& max(abs(vlc2_matrix(129997 : 200001, n))) > vlrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h16(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('v_l_c_2', 'FontSize', 14);
hold all;

figure(17);
if  max(abs(idc1_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc1_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h17(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
```

```
    hold all;
elseif max(abs(idc1_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc1_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h17(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc1_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc1_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h17(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc1_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc1_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h17(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('I_D_C_1', 'FontSize', 14);
hold all;

figure(18);
if  max(abs(idc2_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc2_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h18(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc2_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc2_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
```

```
    h18(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc2_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc2_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs', 'markersize',
    5, 'LineWidth', 2);
    h18(3) = plot(Kpdc1, Kpdc2, 'cs', 'markersize',
    5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc2_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc2_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h18(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('I_D_C_2', 'FontSize', 14);
hold all;

figure(19);
if  max(abs(idc3_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc3_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h19(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc3_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc3_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h19(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc3_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc3_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
```

```
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h19(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc3_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc3_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    h19(4) = plot(Kpdc1, Kpdc2, 'rx',
    'markersize', 5, 'LineWidth', 2);
    hold all;
end
grid on;
xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
title('I_D_C_3', 'FontSize', 14);
hold all;

figure(20);
if  max(abs(idc4_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc4_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    h20(1) = plot(Kpdc1, Kpdc2, 'g^',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc4_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc4_matrix(129997 : 200001, n))) < idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle','none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    h20(2) = plot(Kpdc1, Kpdc2, 'color',
    [0.8500, 0.3250, 0.0980], 'linestyle', 'none',
    'marker', 'o', 'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc4_matrix(99996 : 129996, n))) < idcrefmax
&& max(abs(idc4_matrix(129997 : 200001, n))) > idcrefmax
    hold on;
    plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    h20(3) = plot(Kpdc1, Kpdc2, 'cs',
    'markersize', 5, 'LineWidth', 2);
    hold all;
elseif max(abs(idc4_matrix(99996 : 129996, n))) > idcrefmax
&& max(abs(idc4_matrix(129997 : 200001, n))) > idcrefmax
```

```
            hold on;
            plot(Kpdc1, Kpdc2, 'rx',
            'markersize', 5, 'LineWidth', 2);
            h20(4) = plot(Kpdc1, Kpdc2, 'rx',
            'markersize', 5, 'LineWidth', 2);
            hold all;
        end
        grid on;
        xlabel('K_p_D_C_1 (W/V)', 'FontSize', 14);
        ylabel('K_p_D_C_2 (W/V)', 'FontSize', 14);
        title('I_D_C_4', 'FontSize', 14);
        hold all;
    end
end

figure(1)
hold all;
if h1(1) == 0 && h1(2) == 0 && h1(3) == 0
    legend('nass and natr');
elseif h1(1) == 0 && h1(3) == 0 && h1(4) == 0
    legend('ass and natr');
elseif h1(2) == 0 && h1(3) == 0 && h1(4) == 0
    legend('ass and atr');
elseif h1(1) == 0 && h1(2) == 0 && h1(4) == 0
    legend('nass and atr');
elseif h1(1) == 0 && h1(2) == 0
    legend(h1([3 4]), 'nass and atr', 'nass and natr');
elseif h1(1) == 0 && h1(3) == 0
    legend(h1([2 4]), 'ass and natr', 'nass and natr');
elseif h1(1) == 0 && h1(4) == 0
    legend(h1([2 3]), 'ass and natr', 'nass and atr');
elseif h1(2) == 0 && h1(3) == 0
    legend(h1([1 4]), 'ass and atr', 'nass and natr');
elseif h1(2) == 0 && h1(4) == 0
    legend(h1([1 3]), 'ass and atr', 'nass and atr');
elseif h1(3) == 0 && h1(4) == 0
    legend(h1([1 2]), 'ass and atr', 'ass and natr');
elseif h1(1) == 0
    legend(h1([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h1(2) == 0
    legend(h1([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h1(3) == 0
    legend(h1([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h1(4) == 0
    legend(h1([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
```

```
else
    legend(h1, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(2)
hold all;
if h2(1) == 0 && h2(2) == 0 && h2(3) == 0
    legend('nass and natr');
elseif h2(1) == 0 && h2(3) == 0 && h2(4) == 0
    legend('ass and natr');
elseif h2(2) == 0 && h2(3) == 0 && h2(4) == 0
    legend('ass and atr');
elseif h2(1) == 0 && h2(2) == 0 && h2(4) == 0
    legend('nass and atr');
elseif h2(1) == 0 && h2(2) == 0
    legend(h2([3 4]), 'nass and atr', 'nass and natr');
elseif h2(1) == 0 && h2(3) == 0
    legend(h2([2 4]), 'ass and natr', 'nass and natr');
elseif h2(1) == 0 && h2(4) == 0
    legend(h2([2 3]), 'ass and natr', 'nass and atr');
elseif h2(2) == 0 && h2(3) == 0
    legend(h2([1 4]), 'ass and atr', 'nass and natr');
elseif h2(2) == 0 && h2(4) == 0
    legend(h2([1 3]), 'ass and atr', 'nass and atr');
elseif h2(3) == 0 && h2(4) == 0
    legend(h2([1 2]), 'ass and atr', 'ass and natr');
elseif h2(1) == 0
    legend(h2([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h2(2) == 0
    legend(h2([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h2(3) == 0
    legend(h2([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h2(4) == 0
    legend(h2([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h2, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(3)
hold all;
if h3(1) == 0 && h3(2) == 0 && h3(3) == 0
    legend('nass and natr');
elseif h3(1) == 0 && h3(3) == 0 && h3(4) == 0
```

```
    legend('ass and natr');
elseif h3(2) == 0 && h3(3) == 0 && h3(4) == 0
    legend('ass and atr');
elseif h3(1) == 0 && h3(2) == 0 && h3(4) == 0
    legend('nass and atr');
elseif h3(1) == 0 && h3(2) == 0
    legend(h3([3 4]), 'nass and atr', 'nass and natr');
elseif h3(1) == 0 && h3(3) == 0
    legend(h3([2 4]), 'ass and natr', 'nass and natr');
elseif h3(1) == 0 && h3(4) == 0
    legend(h3([2 3]), 'ass and natr', 'nass and atr');
elseif h3(2) == 0 && h3(3) == 0
    legend(h3([1 4]), 'ass and atr', 'nass and natr');
elseif h3(2) == 0 && h3(4) == 0
    legend(h3([1 3]), 'ass and atr', 'nass and atr');
elseif h3(3) == 0 && h3(4) == 0
    legend(h3([1 2]), 'ass and atr', 'ass and natr');
elseif h3(1) == 0
    legend(h3([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h3(2) == 0
    legend(h3([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h3(3) == 0
    legend(h3([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h3(4) == 0
    legend(h3([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h3, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(4)
hold all;
if h4(1) == 0 && h4(2) == 0 && h4(3) == 0
    legend('nass and natr');
elseif h4(1) == 0 && h4(3) == 0 && h4(4) == 0
    legend('ass and natr');
elseif h4(2) == 0 && h4(3) == 0 && h4(4) == 0
    legend('ass and atr');
elseif h4(1) == 0 && h4(2) == 0 && h4(4) == 0
    legend('nass and atr');
elseif h4(1) == 0 && h4(2) == 0
    legend(h4([3 4]), 'nass and atr', 'nass and natr');
elseif h4(1) == 0 && h4(3) == 0
    legend(h4([2 4]), 'ass and natr', 'nass and natr');
elseif h4(1) == 0 && h4(4) == 0
```

```
    legend(h4([2 3]), 'ass and natr', 'nass and atr');
elseif h4(2) == 0 && h4(3) == 0
    legend(h4([1 4]), 'ass and atr', 'nass and natr');
elseif h4(2) == 0 && h4(4) == 0
    legend(h4([1 3]), 'ass and atr', 'nass and atr');
elseif h4(3) == 0 && h4(4) == 0
    legend(h4([1 2]), 'ass and atr', 'ass and natr');
elseif h4(1) == 0
    legend(h4([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h4(2) == 0
    legend(h4([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h4(3) == 0
    legend(h4([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h4(4) == 0
    legend(h4([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h4, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(5)
hold all;
if h5(1) == 0 && h5(2) == 0 && h5(3) == 0
    legend('nass and natr');
elseif h5(1) == 0 && h5(3) == 0 && h5(4) == 0
    legend('ass and natr');
elseif h5(2) == 0 && h5(3) == 0 && h5(4) == 0
    legend('ass and atr');
elseif h5(1) == 0 && h5(2) == 0 && h5(4) == 0
    legend('nass and atr');
elseif h5(1) == 0 && h5(2) == 0
    legend(h5([3 4]), 'nass and atr', 'nass and natr');
elseif h5(1) == 0 && h5(3) == 0
    legend(h5([2 4]), 'ass and natr', 'nass and natr');
elseif h5(1) == 0 && h5(4) == 0
    legend(h5([2 3]), 'ass and natr', 'nass and atr');
elseif h5(2) == 0 && h5(3) == 0
    legend(h5([1 4]), 'ass and atr', 'nass and natr');
elseif h5(2) == 0 && h5(4) == 0
    legend(h5([1 3]), 'ass and atr', 'nass and atr');
elseif h5(3) == 0 && h5(4) == 0
    legend(h5([1 2]), 'ass and atr', 'ass and natr');
elseif h5(1) == 0
    legend(h5([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
```

```
elseif h5(2) == 0
    legend(h5([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h5(3) == 0
    legend(h5([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h5(4) == 0
    legend(h5([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h5, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(6)
hold all;
if h6(1) == 0 && h6(2) == 0 && h6(3) == 0
    legend('nass and natr');
elseif h6(1) == 0 && h6(3) == 0 && h6(4) == 0
    legend('ass and natr');
elseif h6(2) == 0 && h6(3) == 0 && h6(4) == 0
    legend('ass and atr');
elseif h6(1) == 0 && h6(2) == 0 && h6(4) == 0
    legend('nass and atr');
elseif h6(1) == 0 && h6(2) == 0
    legend(h6([3 4]), 'nass and atr', 'nass and natr');
elseif h6(1) == 0 && h6(3) == 0
    legend(h6([2 4]), 'ass and natr', 'nass and natr');
elseif h6(1) == 0 && h6(4) == 0
    legend(h6([2 3]), 'ass and natr', 'nass and atr');
elseif h6(2) == 0 && h6(3) == 0
    legend(h6([1 4]), 'ass and atr', 'nass and natr');
elseif h6(2) == 0 && h6(4) == 0
    legend(h6([1 3]), 'ass and atr', 'nass and atr');
elseif h6(3) == 0 && h6(4) == 0
    legend(h6([1 2]), 'ass and atr', 'ass and natr');
elseif h6(1) == 0
    legend(h6([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h6(2) == 0
    legend(h6([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h6(3) == 0
    legend(h6([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h6(4) == 0
    legend(h6([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
```

```
    legend(h6, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(7)
hold all;
if h7(1) == 0 && h7(2) == 0 && h7(3) == 0
    legend('nass and natr');
elseif h7(1) == 0 && h7(3) == 0 && h7(4) == 0
    legend('ass and natr');
elseif h7(2) == 0 && h7(3) == 0 && h7(4) == 0
    legend('ass and atr');
elseif h7(1) == 0 && h7(2) == 0 && h7(4) == 0
    legend('nass and atr');
elseif h7(1) == 0 && h7(2) == 0
    legend(h7([3 4]), 'nass and atr', 'nass and natr');
elseif h7(1) == 0 && h7(3) == 0
    legend(h7([2 4]), 'ass and natr', 'nass and natr');
elseif h7(1) == 0 && h7(4) == 0
    legend(h7([2 3]), 'ass and natr', 'nass and atr');
elseif h7(2) == 0 && h7(3) == 0
    legend(h7([1 4]), 'ass and atr', 'nass and natr');
elseif h7(2) == 0 && h7(4) == 0
    legend(h7([1 3]), 'ass and atr', 'nass and atr');
elseif h7(3) == 0 && h7(4) == 0
    legend(h7([1 2]), 'ass and atr', 'ass and natr');
elseif h7(1) == 0
    legend(h7([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h7(2) == 0
    legend(h7([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h7(3) == 0
    legend(h7([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h7(4) == 0
    legend(h7([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h7, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(8)
hold all;
if h8(1) == 0 && h8(2) == 0 && h8(3) == 0
    legend('nass and natr');
elseif h8(1) == 0 && h8(3) == 0 && h8(4) == 0
    legend('ass and natr');
```

```
elseif h8(2) == 0 && h8(3) == 0 && h8(4) == 0
    legend('ass and atr');
elseif h8(1) == 0 && h8(2) == 0 && h8(4) == 0
    legend('nass and atr');
elseif h8(1) == 0 && h8(2) == 0
    legend(h8([3 4]), 'nass and atr', 'nass and natr');
elseif h8(1) == 0 && h8(3) == 0
    legend(h8([2 4]), 'ass and natr', 'nass and natr');
elseif h8(1) == 0 && h8(4) == 0
    legend(h8([2 3]), 'ass and natr', 'nass and atr');
elseif h8(2) == 0 && h8(3) == 0
    legend(h8([1 4]), 'ass and atr', 'nass and natr');
elseif h8(2) == 0 && h8(4) == 0
    legend(h8([1 3]), 'ass and atr', 'nass and atr');
elseif h8(3) == 0 && h8(4) == 0
    legend(h8([1 2]), 'ass and atr', 'ass and natr');
elseif h8(1) == 0
    legend(h8([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h8(2) == 0
    legend(h8([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h8(3) == 0
    legend(h8([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h8(4) == 0
    legend(h8([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h8, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(9)
hold all;
if h9(1) == 0 && h9(2) == 0 && h9(3) == 0
    legend('nass and natr');
elseif h9(1) == 0 && h9(3) == 0 && h9(4) == 0
    legend('ass and natr');
elseif h9(2) == 0 && h9(3) == 0 && h9(4) == 0
    legend('ass and atr');
elseif h9(1) == 0 && h9(2) == 0 && h9(4) == 0
    legend('nass and atr');
elseif h9(1) == 0 && h9(2) == 0
    legend(h9([3 4]), 'nass and atr', 'nass and natr');
elseif h9(1) == 0 && h9(3) == 0
    legend(h9([2 4]), 'ass and natr', 'nass and natr');
elseif h9(1) == 0 && h9(4) == 0
    legend(h9([2 3]), 'ass and natr', 'nass and atr');
```

```
elseif h9(2) == 0 && h9(3) == 0
    legend(h9([1 4]), 'ass and atr', 'nass and natr');
elseif h9(2) == 0 && h9(4) == 0
    legend(h9([1 3]), 'ass and atr', 'nass and atr');
elseif h9(3) == 0 && h9(4) == 0
    legend(h9([1 2]), 'ass and atr', 'ass and natr');
elseif h9(1) == 0
    legend(h9([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h9(2) == 0
    legend(h9([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h9(3) == 0
    legend(h9([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h9(4) == 0
    legend(h9([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h9, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(10)
hold all;
if h10(1) == 0 && h10(2) == 0 && h10(3) == 0
    legend('nass and natr');
elseif h10(1) == 0 && h10(3) == 0 && h10(4) == 0
    legend('ass and natr');
elseif h10(2) == 0 && h10(3) == 0 && h10(4) == 0
    legend('ass and atr');
elseif h10(1) == 0 && h10(2) == 0 && h10(4) == 0
    legend('nass and atr');
elseif h10(1) == 0 && h10(2) == 0
    legend(h10([3 4]), 'nass and atr', 'nass and natr');
elseif h10(1) == 0 && h10(3) == 0
    legend(h10([2 4]), 'ass and natr', 'nass and natr');
elseif h10(1) == 0 && h10(4) == 0
    legend(h10([2 3]), 'ass and natr', 'nass and atr');
elseif h10(2) == 0 && h10(3) == 0
    legend(h10([1 4]), 'ass and atr', 'nass and natr');
elseif h10(2) == 0 && h10(4) == 0
    legend(h10([1 3]), 'ass and atr', 'nass and atr');
elseif h10(3) == 0 && h10(4) == 0
    legend(h10([1 2]), 'ass and atr', 'ass and natr');
elseif h10(1) == 0
    legend(h10([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h10(2) == 0
```

```
    legend(h10([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h10(3) == 0
    legend(h10([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h10(4) == 0
    legend(h10([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h10, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(11)
hold all;
if h11(1) == 0 && h11(2) == 0 && h11(3) == 0
    legend('nass and natr');
elseif h11(1) == 0 && h11(3) == 0 && h11(4) == 0
    legend('ass and natr');
elseif h11(2) == 0 && h11(3) == 0 && h11(4) == 0
    legend('ass and atr');
elseif h11(1) == 0 && h11(2) == 0 && h11(4) == 0
    legend('nass and atr');
elseif h11(1) == 0 && h11(2) == 0
    legend(h11([3 4]), 'nass and atr', 'nass and natr');
elseif h11(1) == 0 && h11(3) == 0
    legend(h11([2 4]), 'ass and natr', 'nass and natr');
elseif h11(1) == 0 && h11(4) == 0
    legend(h11([2 3]), 'ass and natr', 'nass and atr');
elseif h11(2) == 0 && h11(3) == 0
    legend(h11([1 4]), 'ass and atr', 'nass and natr');
elseif h11(2) == 0 && h11(4) == 0
    legend(h11([1 3]), 'ass and atr', 'nass and atr');
elseif h11(3) == 0 && h11(4) == 0
    legend(h11([1 2]), 'ass and atr', 'ass and natr');
elseif h11(1) == 0
    legend(h11([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h11(2) == 0
    legend(h11([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h11(3) == 0
    legend(h11([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h11(4) == 0
    legend(h11([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h11, 'ass and atr', 'ass and natr',
```

```
    'nass and atr', 'nass and natr')
end

figure(12)
hold all;
if h12(1) == 0 && h12(2) == 0 && h12(3) == 0
    legend('nass and natr');
elseif h12(1) == 0 && h12(3) == 0 && h12(4) == 0
    legend('ass and natr');
elseif h12(2) == 0 && h12(3) == 0 && h12(4) == 0
    legend('ass and atr');
elseif h12(1) == 0 && h12(2) == 0 && h12(4) == 0
    legend('nass and atr');
elseif h12(1) == 0 && h12(2) == 0
    legend(h12([3 4]), 'nass and atr', 'nass and natr');
elseif h12(1) == 0 && h12(3) == 0
    legend(h12([2 4]), 'ass and natr', 'nass and natr');
elseif h12(1) == 0 && h12(4) == 0
    legend(h12([2 3]), 'ass and natr', 'nass and atr');
elseif h12(2) == 0 && h12(3) == 0
    legend(h12([1 4]), 'ass and atr', 'nass and natr');
elseif h12(2) == 0 && h12(4) == 0
    legend(h12([1 3]), 'ass and atr', 'nass and atr');
elseif h12(3) == 0 && h12(4) == 0
    legend(h12([1 2]), 'ass and atr', 'ass and natr');
elseif h12(1) == 0
    legend(h12([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h12(2) == 0
    legend(h12([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h12(3) == 0
    legend(h12([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h12(4) == 0
    legend(h12([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h12, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(13)
hold all;
if h13(1) == 0 && h13(2) == 0 && h13(3) == 0
    legend('nass and natr');
elseif h13(1) == 0 && h13(3) == 0 && h13(4) == 0
    legend('ass and natr');
elseif h13(2) == 0 && h13(3) == 0 && h13(4) == 0
```

```
    legend('ass and atr');
elseif h13(1) == 0 && h13(2) == 0 && h13(4) == 0
    legend('nass and atr');
elseif h13(1) == 0 && h13(2) == 0
    legend(h13([3 4]), 'nass and atr', 'nass and natr');
elseif h13(1) == 0 && h13(3) == 0
    legend(h13([2 4]), 'ass and natr', 'nass and natr');
elseif h13(1) == 0 && h13(4) == 0
    legend(h13([2 3]), 'ass and natr', 'nass and atr');
elseif h13(2) == 0 && h13(3) == 0
    legend(h13([1 4]), 'ass and atr', 'nass and natr');
elseif h13(2) == 0 && h13(4) == 0
    legend(h13([1 3]), 'ass and atr', 'nass and atr');
elseif h13(3) == 0 && h13(4) == 0
    legend(h13([1 2]), 'ass and atr', 'ass and natr');
elseif h13(1) == 0
    legend(h13([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h13(2) == 0
    legend(h13([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h13(3) == 0
    legend(h13([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h13(4) == 0
    legend(h13([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h13, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(14)
hold all;
if h14(1) == 0 && h14(2) == 0 && h14(3) == 0
    legend('nass and natr');
elseif h14(1) == 0 && h14(3) == 0 && h14(4) == 0
    legend('ass and natr');
elseif h14(2) == 0 && h14(3) == 0 && h14(4) == 0
    legend('ass and atr');
elseif h14(1) == 0 && h14(2) == 0 && h14(4) == 0
    legend('nass and atr');
elseif h14(1) == 0 && h14(2) == 0
    legend(h14([3 4]), 'nass and atr', 'nass and natr');
elseif h14(1) == 0 && h14(3) == 0
    legend(h14([2 4]), 'ass and natr', 'nass and natr');
elseif h14(1) == 0 && h14(4) == 0
    legend(h14([2 3]), 'ass and natr', 'nass and atr');
elseif h14(2) == 0 && h14(3) == 0
```

```
    legend(h14([1 4]), 'ass and atr', 'nass and natr');
elseif h14(2) == 0 && h14(4) == 0
    legend(h14([1 3]), 'ass and atr', 'nass and atr');
elseif h14(3) == 0 && h14(4) == 0
    legend(h14([1 2]), 'ass and atr', 'ass and natr');
elseif h14(1) == 0
    legend(h14([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h14(2) == 0
    legend(h14([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h14(3) == 0
    legend(h14([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h14(4) == 0
    legend(h14([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h14, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(15)
hold all;
if h15(1) == 0 && h15(2) == 0 && h15(3) == 0
    legend('nass and natr');
elseif h15(1) == 0 && h15(3) == 0 && h15(4) == 0
    legend('ass and natr');
elseif h15(2) == 0 && h15(3) == 0 && h15(4) == 0
    legend('ass and atr');
elseif h15(1) == 0 && h15(2) == 0 && h15(4) == 0
    legend('nass and atr');
elseif h15(1) == 0 && h15(2) == 0
    legend(h15([3 4]), 'nass and atr', 'nass and natr');
elseif h15(1) == 0 && h15(3) == 0
    legend(h15([2 4]), 'ass and natr', 'nass and natr');
elseif h15(1) == 0 && h15(4) == 0
    legend(h15([2 3]), 'ass and natr', 'nass and atr');
elseif h15(2) == 0 && h15(3) == 0
    legend(h15([1 4]), 'ass and atr', 'nass and natr');
elseif h15(2) == 0 && h15(4) == 0
    legend(h15([1 3]), 'ass and atr', 'nass and atr');
elseif h15(3) == 0 && h15(4) == 0
    legend(h15([1 2]), 'ass and atr', 'ass and natr');
elseif h15(1) == 0
    legend(h15([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h15(2) == 0
    legend(h15([1 3 4]), 'ass and atr',
```

```
    'nass and atr', 'nass and natr');
elseif h15(3) == 0
    legend(h15([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h15(4) == 0
    legend(h15([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h15, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(16)
hold all;
if h16(1) == 0 && h16(2) == 0 && h16(3) == 0
    legend('nass and natr');
elseif h16(1) == 0 && h16(3) == 0 && h16(4) == 0
    legend('ass and natr');
elseif h16(2) == 0 && h16(3) == 0 && h16(4) == 0
    legend('ass and atr');
elseif h16(1) == 0 && h16(2) == 0 && h16(4) == 0
    legend('nass and atr');
elseif h16(1) == 0 && h16(2) == 0
    legend(h16([3 4]), 'nass and atr', 'nass and natr');
elseif h16(1) == 0 && h16(3) == 0
    legend(h16([2 4]), 'ass and natr', 'nass and natr');
elseif h16(1) == 0 && h16(4) == 0
    legend(h16([2 3]), 'ass and natr', 'nass and atr');
elseif h16(2) == 0 && h16(3) == 0
    legend(h16([1 4]), 'ass and atr', 'nass and natr');
elseif h16(2) == 0 && h16(4) == 0
    legend(h16([1 3]), 'ass and atr', 'nass and atr');
elseif h16(3) == 0 && h16(4) == 0
    legend(h16([1 2]), 'ass and atr', 'ass and natr');
elseif h16(1) == 0
    legend(h16([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h16(2) == 0
    legend(h16([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h16(3) == 0
    legend(h16([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h16(4) == 0
    legend(h16([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h16, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
```

```
end

figure(17)
hold all;
if h17(1) == 0 && h17(2) == 0 && h17(3) == 0
    legend('nass and natr');
elseif h17(1) == 0 && h17(3) == 0 && h17(4) == 0
    legend('ass and natr');
elseif h17(2) == 0 && h17(3) == 0 && h17(4) == 0
    legend('ass and atr');
elseif h17(1) == 0 && h17(2) == 0 && h17(4) == 0
    legend('nass and atr');
elseif h17(1) == 0 && h17(2) == 0
    legend(h17([3 4]), 'nass and atr', 'nass and natr');
elseif h17(1) == 0 && h17(3) == 0
    legend(h17([2 4]), 'ass and natr', 'nass and natr');
elseif h17(1) == 0 && h17(4) == 0
    legend(h17([2 3]), 'ass and natr', 'nass and atr');
elseif h17(2) == 0 && h17(3) == 0
    legend(h17([1 4]), 'ass and atr', 'nass and natr');
elseif h17(2) == 0 && h17(4) == 0
    legend(h17([1 3]), 'ass and atr', 'nass and atr');
elseif h17(3) == 0 && h17(4) == 0
    legend(h17([1 2]), 'ass and atr', 'ass and natr');
elseif h17(1) == 0
    legend(h17([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h17(2) == 0
    legend(h17([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h17(3) == 0
    legend(h17([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h17(4) == 0
    legend(h17([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h17, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(18)
hold all;
if h18(1) == 0 && h18(2) == 0 && h18(3) == 0
    legend('nass and natr');
elseif h18(1) == 0 && h18(3) == 0 && h18(4) == 0
    legend('ass and natr');
elseif h18(2) == 0 && h18(3) == 0 && h18(4) == 0
    legend('ass and atr');
```

```
elseif h18(1) == 0 && h18(2) == 0 && h18(4) == 0
    legend('nass and atr');
elseif h18(1) == 0 && h18(2) == 0
    legend(h18([3 4]), 'nass and atr', 'nass and natr');
elseif h18(1) == 0 && h18(3) == 0
    legend(h18([2 4]), 'ass and natr', 'nass and natr');
elseif h18(1) == 0 && h18(4) == 0
    legend(h18([2 3]), 'ass and natr', 'nass and atr');
elseif h18(2) == 0 && h18(3) == 0
    legend(h18([1 4]), 'ass and atr', 'nass and natr');
elseif h18(2) == 0 && h18(4) == 0
    legend(h18([1 3]), 'ass and atr', 'nass and atr');
elseif h18(3) == 0 && h18(4) == 0
    legend(h18([1 2]), 'ass and atr', 'ass and natr');
elseif h18(1) == 0
    legend(h18([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h18(2) == 0
    legend(h18([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h18(3) == 0
    legend(h18([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h18(4) == 0
    legend(h18([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h18, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(19)
hold all;
if h19(1) == 0 && h19(2) == 0 && h19(3) == 0
    legend('nass and natr');
elseif h19(1) == 0 && h19(3) == 0 && h19(4) == 0
    legend('ass and natr');
elseif h19(2) == 0 && h19(3) == 0 && h19(4) == 0
    legend('ass and atr');
elseif h19(1) == 0 && h19(2) == 0 && h19(4) == 0
    legend('nass and atr');
elseif h19(1) == 0 && h19(2) == 0
    legend(h19([3 4]), 'nass and atr', 'nass and natr');
elseif h19(1) == 0 && h19(3) == 0
    legend(h19([2 4]), 'ass and natr', 'nass and natr');
elseif h19(1) == 0 && h19(4) == 0
    legend(h19([2 3]), 'ass and natr', 'nass and atr');
elseif h19(2) == 0 && h19(3) == 0
    legend(h19([1 4]), 'ass and atr', 'nass and natr');
```

```
elseif h19(2) == 0 && h19(4) == 0
    legend(h19([1 3]), 'ass and atr', 'nass and atr');
elseif h19(3) == 0 && h19(4) == 0
    legend(h19([1 2]), 'ass and atr', 'ass and natr');
elseif h19(1) == 0
    legend(h19([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h19(2) == 0
    legend(h19([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
elseif h19(3) == 0
    legend(h19([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h19(4) == 0
    legend(h19([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h19, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end

figure(20)
hold all;
if h20(1) == 0 && h20(2) == 0 && h20(3) == 0
    legend('nass and natr');
elseif h20(1) == 0 && h20(3) == 0 && h20(4) == 0
    legend('ass and natr');
elseif h20(2) == 0 && h20(3) == 0 && h20(4) == 0
    legend('ass and atr');
elseif h20(1) == 0 && h20(2) == 0 && h20(4) == 0
    legend('nass and atr');
elseif h20(1) == 0 && h20(2) == 0
    legend(h20([3 4]), 'nass and atr', 'nass and natr');
elseif h20(1) == 0 && h20(3) == 0
    legend(h20([2 4]), 'ass and natr', 'nass and natr');
elseif h20(1) == 0 && h20(4) == 0
    legend(h20([2 3]), 'ass and natr', 'nass and atr');
elseif h20(2) == 0 && h20(3) == 0
    legend(h20([1 4]), 'ass and atr', 'nass and natr');
elseif h20(2) == 0 && h20(4) == 0
    legend(h20([1 3]), 'ass and atr', 'nass and atr');
elseif h20(3) == 0 && h20(4) == 0
    legend(h20([1 2]), 'ass and atr', 'ass and natr');
elseif h20(1) == 0
    legend(h20([2 3 4]), 'ass and natr',
    'nass and atr', 'nass and natr');
elseif h20(2) == 0
    legend(h20([1 3 4]), 'ass and atr',
    'nass and atr', 'nass and natr');
```

```
elseif h20(3) == 0
    legend(h20([1 2 4]), 'ass and atr',
    'ass and natr', 'nass and natr');
elseif h20(4) == 0
    legend(h20([1 2 3]), 'ass and atr',
    'ass and natr', 'nass and atr');
else
    legend(h20, 'ass and atr', 'ass and natr',
    'nass and atr', 'nass and natr')
end
```